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Fat and Oil Resources and Industry of Brazil

Brazil is richly endowed with oil-yielding plants—dozens of species in abundant supply, especially many kinds of palm. That successful exploitation of these natural and cultivated resources is largely dependent on economic factors and that such exploitation is important in the domestic economy of the country are the principal theses of this article.

KLARE S. MARKLEY[1]

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Introduction

The United States of Brazil occupies nearly half of the continent of South America and has an area of 3,286,344 square miles, of which 98.7% is land and only 1.3% water, principally rivers. It is surpassed in area only by the Soviet Union, China and the Dominion of Canada. Brazil's estimated population, however, is only 57.9 million, as of January 1, 1955, or 17.6 per square mile. According to the 1950 census, 25.8% of the population lived in towns or cities over 50,000, and 8.8% in the cities of Rio de Janeiro and São Paulo. The population is predominantly rural and is concentrated in a narrow belt extending only a short distance back from the coast.

Except for air transport, which is generally good, much of Brazil's vast interior territory is isolated from the densely populated centers, and these centers are, for the most part, isolated from one another except for air or water transport. In 1953 the total mileage of Brazil's railroads was slightly less than 23,000. In the same year there were reported to be in existence a total of 8,690 miles of Federal highways and 37,341 miles of State highways. There were 649,966 motor vehicles, comprising 337,539 automobiles, 289,261 trucks and 23,166 buses. Of these, 209,492 automobiles, 161,377 trucks and 10,185 buses were registered in the Federal District and the State of São Paulo.

All of the north of Brazil, consisting of the States of Pará and Amazonas and the Territories of Amapá, Rio Branco, Guaporé and Acre, with a total area of 1,382,235 square miles or more than five times that of Texas, has a population of

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only 1,974,000, of which 1,193,000 are in the State of Pará. The State of Mato Grosso, with an area of 484,486 square miles or slightly less than that of Texas, New Mexico and Arizona combined, has a population of only 558,000.

It is obvious from the paucity of transportation and population that much of Brazil is unknown, even to Brazilians, and it is not surprising, therefore, that many misconceptions concerning this great land are held by many people. Not a few of these misconceptions pertain to Brazil's resources in fats and oils, and to the raw materials from which they are derived. In the following report an effort has been made to analyze the trends in the fat and oil industry during the past decade and a half as factually and realistically as available data and information have permitted and to learn what these trends may imply with respect to the future. The period 1940–54 was chosen because it covers the years of World War II, when Brazil was cut off almost completely from her former European markets, and the following decade, during which the present trend toward industrialization began. It is also a period for which official statistics are readily accessible and more reliable.

Production of Vegetable Oils

For simplicity of discussion, the vegetable oils of Brazil can be divided into four groups, corresponding to their primary uses: a) edible, b) soap and tinplate, c) drying and industrial, d) miscellaneous. This classification is not entirely rigid because small amounts of edible oils as well as castor and linseed oils are used in manufacturing soap, and at times various amounts of lauric acid soap oils are used for culinary purposes. The miscellaneous group contains cocobutter which enters edible products, pharmaceuticals, cosmetics, etc., as well as various minor oils unspecified by name in Brazilian statistics. Soaps and tinplate oils could also be classified as industrial, but, in general, the former are all very similar in chemical composition and in this respect differ from the other oils classified as industrial.

TABLE I

PRODUCTION OF VEGETABLE OILS IN BRAZIL IN 1954 IN METRIC TONS [a]

Edible	
Corn	2,184
Cottonseed	85,812
Peanut	41,391
Sesame	1,710
Total edible	131,097
Soap & tinplate	
Babaçu	34,882
Coconut	373
Murumuru	295
Palm (dendê)	1,932 [b]
Tucum	1,483
Ucuhuba	1,291
Total soap etc.	40,256
Drying & Industrial	
Cashew [c]	201
Castor	42,117
Linseed	9,813
Oiticica	5,819
Tung	1,362
Total Drying	59,309
Miscellaneous	
Cocobutter	5,919
Others [d]	5,935 [e]
Total misc.	11,854
Grand total	242,516

[a] Source: Anuario Estatistico do Brasil, Conselho Nacional de Estatistica, Rio de Janeiro.
[b] This figure for dendê is considerably lower than that reported by the Departamento Estadual de Estatistica (Bahia).
[c] Refers to cashew shell liquid, not to cashew oil.
[d] See text for explanation of others.
[e] Includes 2,583 m. tons of soybean oil.

In Table I there are assembled figures for the production of the individual vegetable oils in each group, the totals for the group, and the grand totals of all oils for the year 1954. Nearly all of Brazil's edible vegetable oils are derived from cultivated plants, principally cotton, whereas almost all soap oils are obtained from wild palms, and almost all drying and industrial oils, except tung, linseed and some castor, from wild plants other than palms. This dependence on

wild indigenous plants for soap, drying and other industrial oils presents a serious problem concerning the future supplies of oils for these uses.

Except for 1954, the production of edible oils has shown but little increase since 1940, whereas there were marked increases in the other groups of oils. As will become evident later, these increases in production of oil do not necessarily reflect increases in the supplies of raw materials, but instead a shift from exportation of these materials to domestic processing. This shift was largely initiated by the need to reduce the volume of exports during World War II because of lack of cargo space and increased domestic demand for oils. After the War this trend continued and was accompanied by a reduction in the export of oils as well as oilseeds because of the increasing domestic demand resulting from increasing population and rapid industrialization of the country. The effect of these changes, as well as the migration of large numbers of families and individuals from rural areas to the rapidly expanding cities, not only reduced exports of oils and oilseeds but recently has also necessitated importation of these commodities.

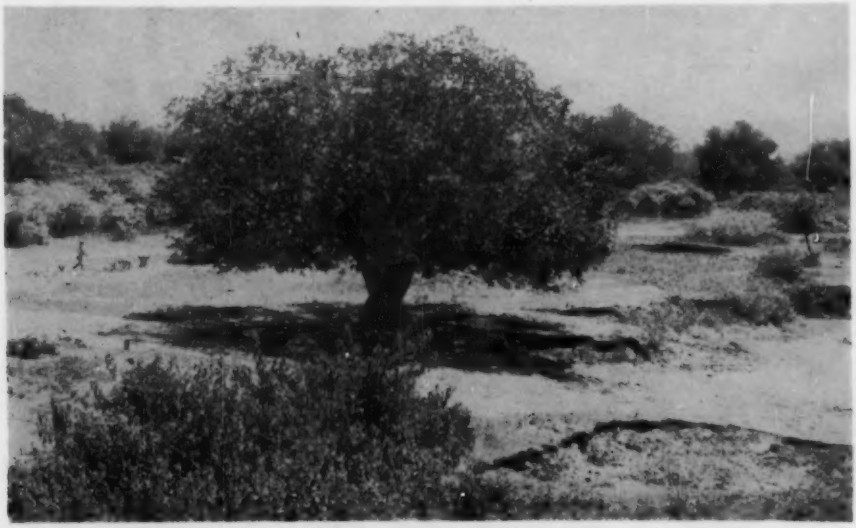

FIG. 1. Oiticica tree (*Licania rigida*).

Edible Oils

Cottonseed. The principal edible oil of Brazil is derived from cottonseed, a byproduct of growing and ginning cotton. The production of cottonseed oil is dependent on the market for cotton fiber, the domestic demand for which has generally been below that for oil, thus necessitating exportation of almost half of the fiber production.

Because of difficulties in marketing cotton abroad and for other reasons, the area planted to cotton has remained relatively static. The area (2.48 million ha[2].) devoted to cotton in 1954 was almost the same (2.49 million ha.) as in 1941 and only slightly less than the 1940–54 average of 2.52 million hectares. Production of cottonseed oil has there-

[2] ha. = hectare = 2.471 acres.

fore also remained relatively static during this period despite an increase in population of over 14 million, or 34%.

The failure of cottonseed oil production to keep pace with the increased need for edible oils has been offset to some extent by the complete cessation of exports of this oil, a marked increase in the production of peanut oil, slight increases in the production of corn and sesame oils, and increased imports of olive oil, which reached 15,279 metric tons in 1954.

Soybean. Further improvement in the supply situation for edible oils may be expected as a result of the erection in Rio Grande do Sul of a large solvent extraction plant for processing soybeans. Production of soybeans in the States of Rio Grande do Sul and São Paulo increased rapidly after they were first introduced into Brazil, although production is practically static at present, owing to lack of sufficient farm machinery to mechanize the crop.

FIG. 2. Cashew nut tree (*Anacardium occidentale*).

The soybean is the only cultivated oilseed exported in significant quantity in recent years. During 1949–54 exports averaged 26,670 m. tons annually. Retention of this seed in Brazil will add an average of about 5,000 tons to the annual supply of edible oils.

FIG. 3. A cocoa plantation (*Theobroma cacao*) in the coastal area in the State of Bahia.

The quantities of soybean oil produced domestically are not reported separately in the Anuário Estatístico do Brasil, but are included under "Others". According to the Serviço Estatistico da Produção, Ministério da Agricultura, production for the years 1950 to 1954 was 332, 171, 475, 1,531 and 2,583 m. tons, respectively.

Peanut. Production of peanuts and peanut oil has increased phenomenally during the past decade and a half. Peak production of peanut oil occurred in 1948 when almost 38,000 m. tons were extracted. Production of this oil declined appreciably during the next five years, owing partly to decreased farm production and partly to increased consumption of peanuts per se. In 1954 production again rose and surpassed the 1948 peak.

Exports of unshelled peanuts amounted

FIG. 4 (Upper). Preparing cocoa butter for shipment.
FIG. 5 (Lower). Packages of cocoa butter ready for export. (Both scenes in a chocolate factory in Ilheus, Bahia).

to 6,375 m. tons in 1949 but dwindled to 12 tons in 1954. Owing to a severe drought in certain areas of the South, the United States of America imported during the 13-month period, July 1, 1954 to July 31, 1955, a total of 54,479 m. tons of shelled peanuts, of which 15,578 m. tons came from Brazil.

FIG. 6. Murumuru palm nuts (*Astrocaryum murumuru*) at a collecting center on the lower Amazon River, waiting shipment to Belém, Pará.

Others. Production of corn oil is small but has been increasing in recent years. This oil is a byproduct of the milling of corn for starch and the manufacture of various food products. Production of this oil is therefore dependent on the demand for other processed corn products. The same is true for the production of corn germ oil, of which 125 m. tons were produced in 1954.

Production of sesame oil is similarly small, but, like corn oil, it has increased slowly during the last decade.

Various quantities of oils classified in

the soap group are consumed for edible purposes. The exact consumption of these oils is unknown and most of it occurs locally in the area where they are produced and other oils are scarce and abnormally costly.

The quantities of edible vegetable oils available for consumption on a per capita basis are low compared with those for the United States and most north European countries. In the United States direct domestic civilian food use of edible oils, exclusive of butter and lard, averaged between 6.1 and 9.4 pounds annually during the period 1940–54, or about twice the consumption in Brazil. Part of this apparent low consumption may be explained by the fact that there is still some home processing of oilseeds in isolated areas, and some local factory production of oils, also in isolated areas, which may not be reported. However, the population in these areas is small, and probably this consumption has little effect on the national average.

Soap and Tinplate Oils

Except for a small amount of coconut oil, all of the oils in the soap and tinplate group of Table I are derived from the seeds and fruits of wild trees. Except for a small and undeterminable quantity which is consumed for edible purposes, all the oils in this group go into the soap industry. During the past several years babaçú has accounted for 80 to 94% of this group; it is the principal lauric acid oil used by the domestic soap industry. The increased production of this oil during the past decade and a half is not a result of any increase in the supplies of babaçú kernels, but the result of a shift of kernels from export to the domestic processing industry. The palm (dendê) oil used in the manufacture of tinplate is imported for reasons discussed below.

Babaçú. No other branch of the oil industry so clearly reflects the changes which Brazilian economy has undergone in recent years as does that of babaçú. Prior to World War II the bulk of the production of babaçú kernels was exported, and little oil was produced for domestic consumption. Processing facilities were expanded toward the end of and immediately following World War II, and the export of kernels declined from the peak of 44,292 m. tons in 1945 to zero in 1952 and 1953. In 1954 the export of babaçú kernels was 44 m. tons. Domestic production of oil rose from slightly over 6,000 tons in 1940 to more than 35,000 tons in 1951 but has declined since then, and prospects for increased production in the future are rather dim. Exports of babaçú oil in 1954 amounted to 23 m. tons.

The shift from export of babaçú kernels to domestic production and consumption of babaçú oil resulted from the increased demand for lauric acid oil by the domestic soap industry, which in turn stems from the rapid growth in population, the rapid industrialization of the country, and the migration in recent years of large numbers of the rural people to the expanding coastal and interior cities. The increase in population, coupled with improved per capita income, has led to a marked expansion in the demand for all types of soaps, toiletries and related products. The foreign exchange situation does not permit importation of these manufactured products or of the basic raw materials used in manufacturing them. Consequently competition is keen for the available lauric acid oils of domestic origin, with the result that they have been priced out of the world market.

Despite the fact that the babaçú palm (*Orbignya speciosa*) and its industrialization have been the subjects of numerous publications and not a few technical investigations, the trees are as little understood today as at any time in the past. The natural babaçú palm forests

are the source of the raw material for this industry. The palm occurs in relatively large numbers, especially in the State of Maranhão where the industry is centered. Piauí and the northern part of the State of Goiaz also have large numbers of these palms. No very exact information is available regarding the total number or the density and distribu-

ing surveys of this type have been developed, they apparently have never been applied to the babaçú palm.

Despite large expenditures of time, effort and money over many years, mechanical processing of babaçú fruit has never proved practical or economical. Failure to accomplish this operation mechanically lies in the inherent nature of

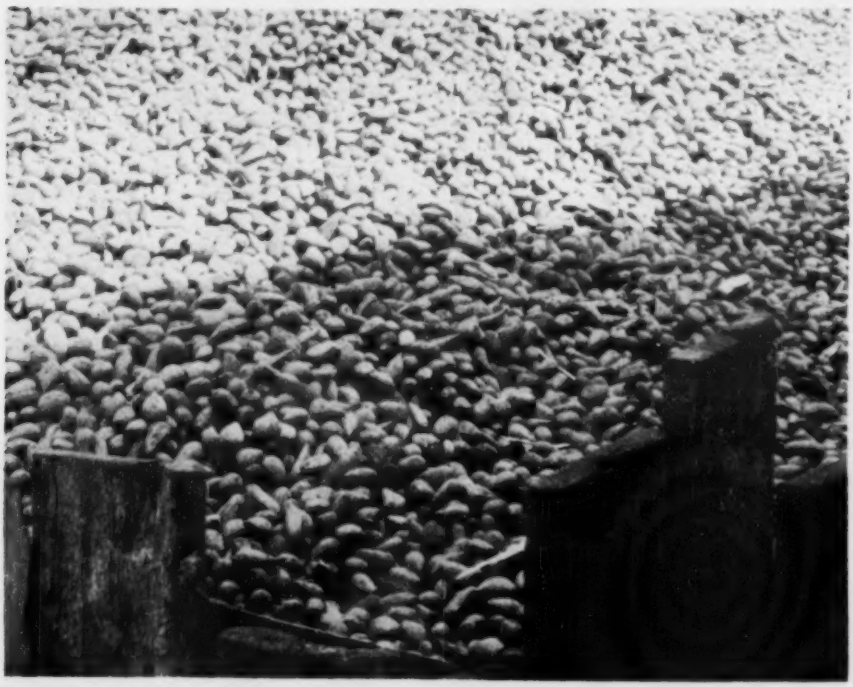

FIG. 7. Murumuru nuts.

tion of this palm, the relative proportion of bearing to non-bearing trees, the average yield of fruit per tree, and, most important of all, the average annual production of oil per unit of area. Comparison of data for the last mentioned with values for the average production of cultivated oilseed crops makes it possible to determine the economic feasibility of exploitating a given area of babaçú. Although techniques for mak-

the fruit which is extremely hard, exceedingly variable in size and in number and size of kernels, and because of the low ratio of economically valuable products to the total weight of the fruit.

The weight of air-dry babaçú fruit varies from 40 to 490 grams. The number of kernels per fruit varies from one to eight; hence the percentage of kernel weight to the weight of the whole fruit varies appreciably, from 0.5 to 17%, and

averages 6%. The oil content of the kernels varies slightly but is about 65%, hence the average oil content per fruit is only about 4%. It is this 4% which constitutes five-sixths of the value of the whole fruit; the presscake remaining after extraction of the oil represents the other one-sixth of the total value. The hull, shell and other residue of the fruit have at present no value except a potentially limited one in a processing plant which might be equipped to use these byproducts as fuel.

Although the estimated number of babaçú palms and annual yield of fruit have generally been highly exaggerated, both are nevertheless very large, and their exploitation presents a problem of recovering economically a small amount of useful product from a large volume of valueless accompanying material. Only two possibilities present themselves: first, of cracking the nuts and separating the kernels close to the place where the fruit is found, and then transporting the kernels to the oil mill; secondly, of transporting the whole fruit to a central cracking and separating center and from there transferring the kernels to the oil mill. Both systems have been tried.

In the first system the fruit is collected by migratory workers or the natives living in or near the palm forests, who collect the fruit and subsequently crack the nuts manually and separate the kernels. In the second system the fruit is similarly collected and subsequently transported to a central plant where the cracking and separating operations are performed mechanically.

The first system requires a large amount of cheap labor, the second a large amount of cheap transport and efficient and economical machinery. According to Leite et al., a head of a family can produce an average of five kilos of kernels per day, or about 500 kilos a year, which, if sold at the high price of Cr$3.00 a kilo, yields for the family only Cr$1,500 [3]. Because of this low income and consequently low social status, the native laborer has been migrating from the babaçú areas to other parts of Brazil where he can improve his economic-social status.

If, on the other hand, the babaçú fruit is collected and transported to a central processing plant, 94 to 96% of relatively worthless material must be moved over considerable distance in an area where roads are almost not existent and water transportation is inadequate and costly. Various schemes for building roads within the babaçú areas and from there to central processing plants have been proposed. Construction and maintenance of such roads could not be justified solely on the basis of the movement of babaçú fruit. Furthermore, opening heretofore inaccessible areas through construction of roads sooner or later leads to clearing of the land and subjecting it to fixed agriculture, a fact which has been amply demonstrated repeatedly in Brazil and elsewhere in Latin America. According to Bondar, 100,000 hectares (247,000 acres), representing at least five million babaçú palms, are cut over and burned annually in the State of Maranhão in order to plant rice and cotton.

Even though the collection and transportation problems could be solved, there still remains the fact that to date, mechanical cracking of the nuts and separation of the kernels have not been solved. The combination of nomadic labor of low productive capacity, inadequate and relatively expensive transportation, and lack of mechanization, but principally the low ratio of oil to total fruit weight, explains why the produc-

[3] At the average 1954 exchange rate of Cr$62.18 to the U.S. dollar at the Rio de Janeiro Stock Exchange, the average annual income per family for this operation was equivalent to $24.12.

tion of babaçú kernels has remained practically static for the past 15 years and why the outlook for the future appears no brighter.

Murumuru and Tucum. Although murumuru (*Astrocaryum murumuru* Mart.) and tucum (*A. tucuma* Mart.) palms are found in considerable numbers in Pará and other areas in Amazonia, they have not been important contributors to the fat and oil economy of Brazil. The total production of oil from both sources has seldom exceeded a thousand tons. Maximum production occurred in 1954 when the total for the two oils amounted to 1,778 m. tons because of an abnormally large production in tucum oil. Tucum kernels were once exported in fairly large quantities and in 1949 reached 13,787 metric tons but since then have declined to practically nothing. The economic pattern of murumuru and tucum is similar to that of the babaçú and other extractive industries.

FIG. 8. Andiroba nuts (*Carapa guianensis*) at a collecting center on the Tocantins River in Pará. Klare S. Markley examining the nuts.

Ucuhuba. Ucuhuba fat is not obtained from a palm but from two species of *Virola*, namely, *V. surinamensis* Warb. and *V. sebifera* Aubl. It is used for the manufacture of soap and candles. This fat, like that from other species of this genus in Venezuela and Guatemala, is very high in myristic acid, 60–65% of the total fatty acids. The ucuhuba tree is found in various places in the Amazon Valley, particularly near the mouth of the river. Production of oil has varied between 650 and 1,600 m. tons a year, and, like other soap oils derived from wild plants, production remains static or is declining, maximum production having occurred in 1941.

Coconut. Except for some recent commercial plantings of African oilpalm in the State of Bahia, the coconut (*Cocos nucifera* L.) is the only oilpalm which is cultivated in Brazil. Although official statistics indicate that the production of coconuts has increased from 133 million in 1938 to 278 million in 1955, production of coconut oil has declined during the past ten years (2,739 m. tons in 1944 to 373 tons in 1954), and the prospects are that it will decline still further. The decline in coconut oil production is the result of the constantly increasing demand and corresponding high prices for coconuts in the edible trade, and export of fresh coconuts for the same purpose which amounted to more than one million units in 1954.

Dendê. The presence of the African oilpalm (*Elaeis guineensis* Jacq.), known in Brazil as dendê, is shrouded in mystery. It is believed that this palm was introduced into the State of Bahia during the days of the slave trade, but whether by the Portuguese or negroes is not known. It is also not known where the seeds were first planted, but it is generally assumed that the palm escaped into the natural forests or into cultivated fields through the agencies of buzzards, rodents and other animals. At least this process can be observed today. The palm is not widely distributed and, except for individual or scattered trees, is confined to a few areas along the coast of Bahia, which are generally separated by considerable distance. In a report of the Bahia Department of Statistics there are enumerated but six dendê zones, only two of which produce significant quantities of oil. Of more than a thousand tons of dendê oil produced in 1952, 809 tons originated in the Cacaueira Zone and 251 in the Recôncave Zone. An aerial survey by the author in 1954 of the dendê palm in Bahia revealed that much of the coastal area was devoid of this palm. The predominant palm was piaçava (*Attalea funifera* Mart.) which flourishes in great numbers between Itaparica and Maraú where the majority of dendê palms are also to be found. The generally accepted figures for the number of these palms in Bahia appear to be exaggerated.

Despite the several centuries during which the dendê palm has been known in Brazil, it has not been subjected to a plantation system of cultivation as has been done in the Far East, Africa and Central America. Such oil as was produced in the past was, and in fact still is, largely recovered by the same primitive methods followed since colonial times. In general, the fruit is boiled with water to soften the pulp, or it is allowed to remain in a pile to ferment for several days without access to air. After the fruit becomes soft it is pounded in a mortar to separate the pulp from the seed. The pulpy mass is transferred to a kettle and boiled with water to separate the oil which rises to the surface. The oil is drawn off and boiled again to evaporate the remaining water, which process is called "drying". The pulpy residue is put on a piece of cloth or in a bag to permit additional oil to drain from it. When produced on a larger scale, the whole fruit is ground in a big

circular stone mortar whose pestle is powered by an ox or other draft animal. The ground mass of pulp and kernels is boiled with water to separate the oil which is further treated as mentioned above. This product is a mixture of pulp and kernel oil.

FIG. 9. Pracaxi tree (*Pentaclethra filamentosa*). Close-up view of flowering branch. Manaus, State of Amazonas.

One small plant owned by the Instituto de Technologia na Fazenda "Mocambo" of the State Secretary of Agriculture, located on the Island of Itaparica, is equipped with a small continuous press of German manufacture for separating the pulp oil. Bunches of fruit are piled on the floor until a sufficient amount accumulates to warrant operation of the plant. The fruit is cut from the stem with a machete, after which it is cooked with water over an open fire in large shallow iron basins outside the factory. The boiled fruit is disintegrated in a small depulping machine which liberates part of the oil. The macerated fruit is cooked with steam in a single stack cooker mounted above the press. The macerated and cooked fruit is

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FIG. 9. Pracaxi tree (*Pentaclethra filamentosa*). Close-up view of flowering branch. Manaus, State of Amazonas.

dropped into the press where the remaining oil is separated. The separated oil is washed twice with water, settled, and the settled oil drawn off and placed in drums for shipment to Salvador. This

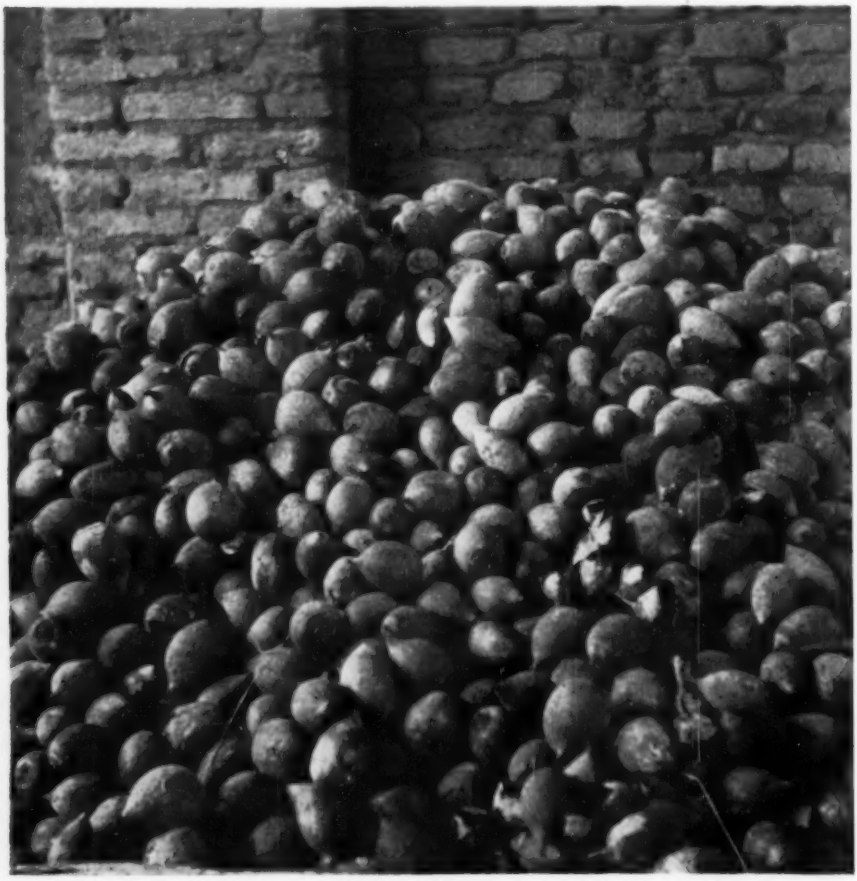

FIG. 10. Babassu nuts (*Orbignya speciosa*), in part from the cluster in Fig. 11, prior to cracking the kernels. Pacoti, Ceará.

plant produced 94 m. tons of oil and 150 tons of kernels in 1952.

The Island of Itaparica has been reported to contain about 300,000 dendê palms, but a ground and aerial survey by the author indicated only about one-tenth of this number, most of which were inaccessible to the oil mill. Here, as on the mainland, the principal palm appeared to be piaçava (*Attalea funifera* Mart.). The dendê palm does not seem well adapted to Itaparica, and many of the trees are sterile, chlorotic, and exhibit other evidence of lack of soil fertility.

Owing to the multiplicity of small producers and the considerable amount of home production and consumption of

dendê, it is difficult to obtain reliable figures for the total annual production of this oil. Even approximate data are unobtainable. The oil is generally very high in free fatty acids; according to one statement, it often contains 25–35% acid. Much of the oil is consumed locally for culinary purposes, generally without refining. That shipped to São Paulo and Rio de Janeiro is consumed in the manufacture of soap.

Attempts to use the oil by Cia. Siderúrgica Nacional at Volta Redonda in the manufacture of hot-dipped tinplate were unsuccessful because of the high free fatty acid content of the oil. It became necessary, therefore, to import palm oil for this purpose from Africa. Imports of palm oil for this use amounted to 573 m. tons in 1953 and 2,086 tons in 1954. It is estimated that at least 5,000 tons annually will eventually be needed for tinplating alone. Because of exchange regulations, imports of palm oil for the manufacture of soap are virtually impossible.

During the past several years the Institute Agronômico do Leste at Cruz das Almas in Bahia and the Instituto Agronômico do Norte at Belém, Pará, have become interested in the development of an oilpalm industry. Both of these Institutes have begun experimental work on a limited scale, but they lack the staff and finances to initiate work on the scale of that being conducted by the West African Institute for Oil Palm Research near Benin City, Nigeria. Furthermore, most of the work is being conducted with selections from wild or semi-wild trees of Bahia, although both Institutes have received a small amount of seed from Africa and elsewhere. In the Territory of Amapá, dendê seedlings are being distributed to small farmers. Between 1952 and 1955 over 31,000 seedlings were distributed to farmers in four municipios (counties) without regard to the problem of transportation and processing of the fruit. This lack of planning can only result in a continuation of the same primitive methods of producing oil as are presently practiced in Bahia.

FIG. 11. The fruiting cluster which furnished some of the nuts in Fig. 10.

In 1954 the firm of S/A Industrias Reunidas F. Matarazzo began planting dendê on a large scale on a barren sandy peninsula southeast of Ituberá in the State of Bahia. The development is under the direction of two former managers of Indonesian oilpalm plantations. Seed for this development is also being selected from wild and semi-wild trees of Bahia. None of the experimental or commercial plantings has attained sufficient age to provide any information on probable yields, adaptability of the

Bahian palms to plantation cultivation, soil fertility or disease problems.

Since Brazil cannot look to increasing supplies of lauric acid oils from the babaçú, tucum, murumurú and other wild palms, and since foreign exchange is unavailable to import copra, palm kernels or palm and coconut oils, only one course appears to offer a solution to what is becoming a serious supply problem, namely, a plantation system of oilpalm cultivation. Because of the seriousness of the problem, the present lack of a realistic approach to planning a program for the development of a coordinated plantation-oil mill system of dendê oil production is greatly to be deplored.

Drying and Other Industrial Oils

The group of oils designated here consists in part of linseed, oiticica and tung, used in the manufacture of protective and decorative coatings. Cashew oil is included, although the kernel oil is actually an edible oil. Castor oil is also included in the group because an appreciable proportion of this oil is dehydrated for use in the manufacture of protective and decorative coatings in the same manner as tung and oiticica oils. Production of this group of oils has steadily increased for more than a decade, and nearly all of the increase has been in castor oil.

Cashew (Cashew Shell Liquid). The figure in Table I refers to cashew shell liquid, not to cashew oil [4]. Cashew shell liquid is produced from the shell of the cashew nut which represents 30 to 40% of the whole nut. The shell liquid constitutes about one-third of the weight of the shell. The liquid is not a fatty oil but a complex mixture of phenolic compounds with long unsaturated side chains which are responsible for both the severe vesicant action and the excellent polymerization properties of the liquid, valuable as a varnish oil.

Although the cashew tree (*Anacardium occidentale* L.) is indigenous to Central and South America, it was taken by early Portuguese traders to Africa and India, where it is presently cultivated. India is the principal producer of cashew nuts and cashew shell liquid for the world market. Cashew shell liquid was first produced in Brazil in 1944 under a U. S. Government procurement contract because of inability to obtain supplies from India. Brazilian production has always been small (200 to 800 m. tons) compared to the Indian production and to the U.S. consumption of this product which normally amounts to 3,000 to 6,000 m. tons annually.

Castor. The castor plant (*Ricinus communis* L.) grows wild in most tropical and subtropical areas of the world. Consequently castor seed or oil is produced in many countries, although only a few of them, principally Brazil, India and the Soviet Union, are responsible for the bulk of the seed and oil entering foreign commerce. Brazil normally accounts for one-third and India one-fourth of the export of this oilseed, while the United States is the largest importer; in 1953 it consumed 70 percent of the total exports from all producing countries.

Brazilian seed comes from wild, semi-wild and cultivated plants, but the proportion obtained from each is unknown. None of the new indehiscent, dwarf and semi-dwarf hybrids and selections developed in the United States is grown commercially in Brazil, although they have been tested at some of the agricultural experiment stations where they have shown the same superior characters as in the United States. Marked changes have occurred in the castor industry of Brazil in the past decade and a half.

[4] The Anuario Estatístico do Brazil erroneously designates cashew shell liquid as cashew oil which, so far as can be determined, is not produced in Brazil for sale or export.

Some production is reported from all of the 20 States of Brazil, but the five States of São Paulo, Ceará, Pernambuco, Bahia and Minas Gerais account for about 92 percent of the total production.

FIG. 12. Removing kernels from cracked babassu fruits. Sitio Palmeira, Municipio Meruca, Ceará.

Except for the two years 1948 and 1949 there has been little change in the total production of castor seed in Brazil during the past 15 years, and such change as has occurred has been generally downward. There have been market fluctuations and a general downward trend in the export of this seed.

Production of castor oil prior to 1940 was relatively insignificant, but, stimulated by the demand for this oil in the United States and the need to conserve cargo space during World War II, domestic processing of seed increased rapidly, and by 1954 production of oil exceeded 42,000 tons. Exports of oil increased steadily until 1951 when they

amounted to nearly 30,000 tons, but by 1954 they were only about half this amount. Current domestic demand for castor oil is estimated to be about 20,000 tons annually, and within the next few years it is predicted that 25,000 to 30,000 tons will be required.

FIG. 13. Cracking babassu fruit on up-turned axe blade fastened in a log of wood. Nut is held on the blade and the blade is driven through the nut by pounding the latter.

Formally castor oil was used in Brazil principally as a medicinal, in the manufacture of soap, and for sulfonation. The two latter uses have increased and to them has been added a demand for dehydrated oil and other products. With the rapid industrialization now in progress, new uses are developing for castor oil, including hydrogenated oil and dibasic esters for the manufacture of nylon, plasticizers and plastics.

The internal demand has resulted in curtailment of exports of both seed and oil, which poses a serious problem for the United States. To meet this problem

one of the largest U.S. processors of castor seed decided to erect a processing plant in Brazil in order to insure a supply of oil for the United States. This concern is now faced with the problem of increasing farm production of castor seed in order to assure the new plant an adequate supply of raw material, especially as other firms are also erecting new processing plants to supply oil for the domestic market.

The recent unfavorable position of Brazil's castor industry is also reflected in U.S. imports of castor seed, which declined from 131,543 m. tons in 1949, of which Brazil furnished 125,193 m. tons, to 51,710 m. tons in 1953, of which Brazil furnished 22,680 tons. On the other hand, U.S. imports of castor oil increased from 4,990 m. tons, all from Brazil, in 1949 to 57,600 m. tons in 1953, of which only 24,040 tons were furnished by Brazil. India is at present the world's largest exporter of castor oil, although a smaller

FIG. 14. Dense stand of babassu palms. State of Piauí.

producer of seed than Brazil. In 1953 India exported 28,587 m. tons of oil compared with 26,749 tons from Brazil; in 1954 India exported 28,192 m. tons of oil compared with 15,676 tons from Brazil; in the first six months of 1955 India exported 21,108 m. tons of oil. Brazilian figures are not yet available for the corresponding period, but exports are believed to be considerably below those for India.

Oiticica. Oiticica oil is obtained from the kernels of the nut of the oiticica tree (*Licania rigida* Benth.) which grows wild in the States of Ceará, Paraíba, Piauí and Rio Grande do Norte, generally in valleys and lowlands, especially along the banks of rivers. There is no reliable information concerning the total number of these trees in Brazil, although statements have been made that Ceará and Piauí each contain more than a million trees. Felling of the tree is prohibited by law as a conservation measure. Exportation of the seed is also prohibited to prevent introduction of the tree elsewhere. In its natural state the tree is subject to cycles of high and low yields, and individual trees exhibit extreme variations in yield. Harvesting the fruit is done by shaking or knocking it from the trees with sticks or stones, after which it is picked from the ground.

The kernels constitute 60 to 75% of the weight of the seed, and they contain 55 to 63% oil. In general, the oil resembles tung oil because, like tung, it contains an unsaturated acid (licanic) having a triply conjugated system of double bonds. However, this acid also contains a keto group which the tung oil acid (eleaestearic) does not, and the oil also contains a larger proportion of saturated acids than tung. In general, oiticica oil has the same but more limited uses as tung, and it requires modifications of formulations when substituted for tung. This difference in behavior is usually reflected in a lower price for oiticica oil compared with tung. This differential may be small or considerable, depending on the supply situation and other factors.[5]

The oiticica oil industry is centered in Ceará and, especially, in Fortaleza. About 20 mills process oiticica, of which 14 are located in Ceará. The largest of these is Brazil Oiticica S.A. which is reported to have a total crushing capacity of 3,500 tons per month for oiticica, castor and cashew shell.

The maximum production of oiticica oil (18,191 m. tons) occurred in 1941, followed by a marked drop until after World War II. By 1948 production recovered to almost the 1941 level but since then the trend has been generally downward, and there is little expectation that it will again attain the previous peaks.

Up to the year 1948 exports of oil were nearly equal to the total production, but from that year forward production and exports have diverged appreciably. Between the years 1948 and 1954 the accumulated difference has amounted to 14,547 tons of oil which presumably have been consumed in the domestic protective and decorative coating industry.

The future of the oiticica oil industry, like that of most of the extractive industries of Brazil and elsewhere in the Latin America, is a beclouded one. Oiticica oil must compete with tung, dehydrated castor oil, and in some instances with linseed oil. The decreasing availability or increasing cost of labor required for collecting seed is making it more and more difficult to obtain sufficient raw material at a price which will permit the oil to be produced at a price to meet world competition. Perhaps a plantation system of growing the oiticica tree might solve the problem but this has not been proven as yet, even experimentally.

[5] Prices f.o.b. New York, tank car lots, were: tung, 25¼ cents; oiticica, 13½–13¾ cents. Oil, Paint and Drug Reporter, October 31, 1955.

Tung. The tung tree (*Aleurites fordii* Hemsl.) was introduced into Argentina in 1927, and during the 1930's cultivation spread to Paraguay and Brazil. In Brazil its cultivation is confined principally to the State of Paraná adjacent to the principal producing areas of Argentina and Paraguay. Plantings were also made in the States of Rio Grande do Sul, Santa Catarina and São Paulo. The total planted area increased to 10,676 hectares and 1,816,000 trees by 1948. Ravishes of frost, low prices for the fruit, and inadequate processing and transportation facilities discouraged further expansion and eventually led to cutting down planted trees so that by 1954 the total number of producing trees was reduced to less than one million. Production of oil, however, continued to grow with increasing maturity and better care of the remaining trees until it reached 1,362 m. tons in 1954. It is unlikely that there will be any further expansion

FIG. 15. Licuri, or ouricury, palm (*Cocos coronata* or *Syagrus coronata*). State of Bahia.

FIG. 16. Murumuru palms (*Astrocaryum murumuru*). Manaus, Amazonas.

in the cultivation of this tree in Brazil, since other more remunerative crops can be grown in the tung area. In recent years there has been no export of tung oil, for the entire production has been consumed in the domestic protective and decorative coating industry.

Linseed. Flax is grown almost exclusively in the State of Rio Grande do Sul adjacent to Uruguay, although there is a small production in the States of Paraná and Santa Catarina. No data are published in the Anuário Estatístico do Brasil concerning this crop or commerce in its seed. The only avaliable data are for the production of oil, one figure for which is included in Table I, believed to include oil produced from domestically grown as well as imported seed.

It has been reported that 1,967 m. tons of flaxseed were imported from Uruguay in 1953, and 8,092 tons in 1954 plus 20 tons from the Netherlands. In 1954 there were also imported 336 tons of hempseed and 6,696 kilos of linseed oil.

Apparently there is no export of linseed oil, owing to the domestic demand by the protective and decorative coating industry. It is unlikely that there will be any appreciable expansion of flax production in the near future because suitable land for this crop can be more profitably utilized for other crops, especially for wheat.

In general, Brazil can look to decreasing markets for drying oils in the United States because of technological changes which have occurred in the protective and decorative coating industry. According to the U.S. Department of Agriculture, the use of drying oils increased only about 25% in the last two decades, while the production of paints, varnishes and lacquers nearly doubled. The basic cause of this changed outlook is the increased use of non-oil or partly oil material instead of oils in the formulation of various products. This shift is still in progress and may be expected to be intensified.

The principal changes which have affected the demand for drying oils in the United States have been the introduction and widespread use of latex-base instead of oil-base paints, the increased use of synthetics in the manufacture of paint and non-paint products, and the increasing use of tall oil, soybean oil and fish oil in the manufacture of paint and non-paint products. These changes have reduced the fast-drying tung, oiticica and dehydrated castor oils to the rank of

minor oils. "The future for drying oils, based on present technology, is not promising."

Miscellaneous Oils

This group contains cocobutter, a by-product of cocoa, which is used in the manufacture of chocolate, pharmaceutical preparations and cosmetics. It also includes a group of oils designated in the Anuário Estatístico do Brasil as "Others." It is composed of four types of products: *a*) glyceride oils, produced in too small quantity to justify separate enumeration; *b*) essential or ethereal oils, produced in similar small quantities; *c*) glyceride oils not heretofore produced in Brazil; *d*) miscellaneous products having an appreciable oil content and not otherwise classified.

The products listed as "Others" in Table I varies considerably from year to year. In 1954, for example, the following were reported among "others": *a*) andirobi, buriti, macaúba, ouricuri, piassava, Brazil nut; *b*) lemon, lemongrass, orange, tangerine, mustard; *c*) corn germ, soybean; *d*) copaiba (resin), coconut milk.

During the war years 1941–44 the total production of this group of oils averaged 8,209 m. tons per year. From 1945–53 the average production was only 3,509 m. tons per year. In 1954 the figure rose to 5,934 m. tons because of the inclusion of 2,582 tons of soybean oil, a vegetable oil relatively new to Brazil.

At times varying quantities of these oils have been exported, but, except for cocobutter, total exports of miscellaneous oils in 1954 amounted to only 23 m. tons.

Cocobutter. The cacau or cacao industry of Brazil is centered in Bahia, although there is some production of cacao in Espirito Santo, Pará and Amazonas. Production of cocobutter, however, is almost entirely confined to Bahia which produced all except 25 tons of the 1953 output of 10,050 m. tons. Production of cocobutter has varied erratically from year to year but between 1944 and 1952 averaged a little over 6,000 m. tons a year; in 1953 it rose to 10,050 tons.

FIG. 17. The author, standing next to Equatorial Marker in the Territory of Amapá. Plaque on marker reads as follows:

Marinha do Brasil
Directoria Hidrografia e
Navegaçao

Latitude
00° 00′ 00″

1952

Patauá. The patauá or batauá palm (*Jessenia bataua* (Mart.) Burrett.) is unusual because it contains less than one percent of oil in the kernel but 18–24% of oil in the pulp, which chemically is almost identical with olive oil. The palm is fairly widespread, although not exceedingly numerous in the humid areas

in Pará and Amazonas and in the Orinoco River Valley and Gulf of Paria in Venezuela, where it is commonly called "seje palm".

Because of the unique character of the pulp oil, it has been examined by many investigators from 1910 to date. According to Pinto, the pulp oil, which is light greenish-yellow, is composed of 7.1% palmitic, 8.8% stearic, 72.9% oleic and 5.2% linoleic acid, 4.9% glycerol and 1.3% unsaponifiable matter. Wohlers, who examined the pure oil and mixtures of the oil with olive oil, showed that the two oils are indistinguishable except for their respective contents of squalene. She showed that 60 samples of olive oil varied in squalene content from 300–635 mg./100 g., whereas patauá contained only 6–11 mg./100 g. The two oils are therefore distinguishable only by means of the Fitelson test.

FIG. 18. Peanuts and castors interplanted. Sape, Paraiba.

The natives in Venezuela and Brazil have from time immemorial recovered

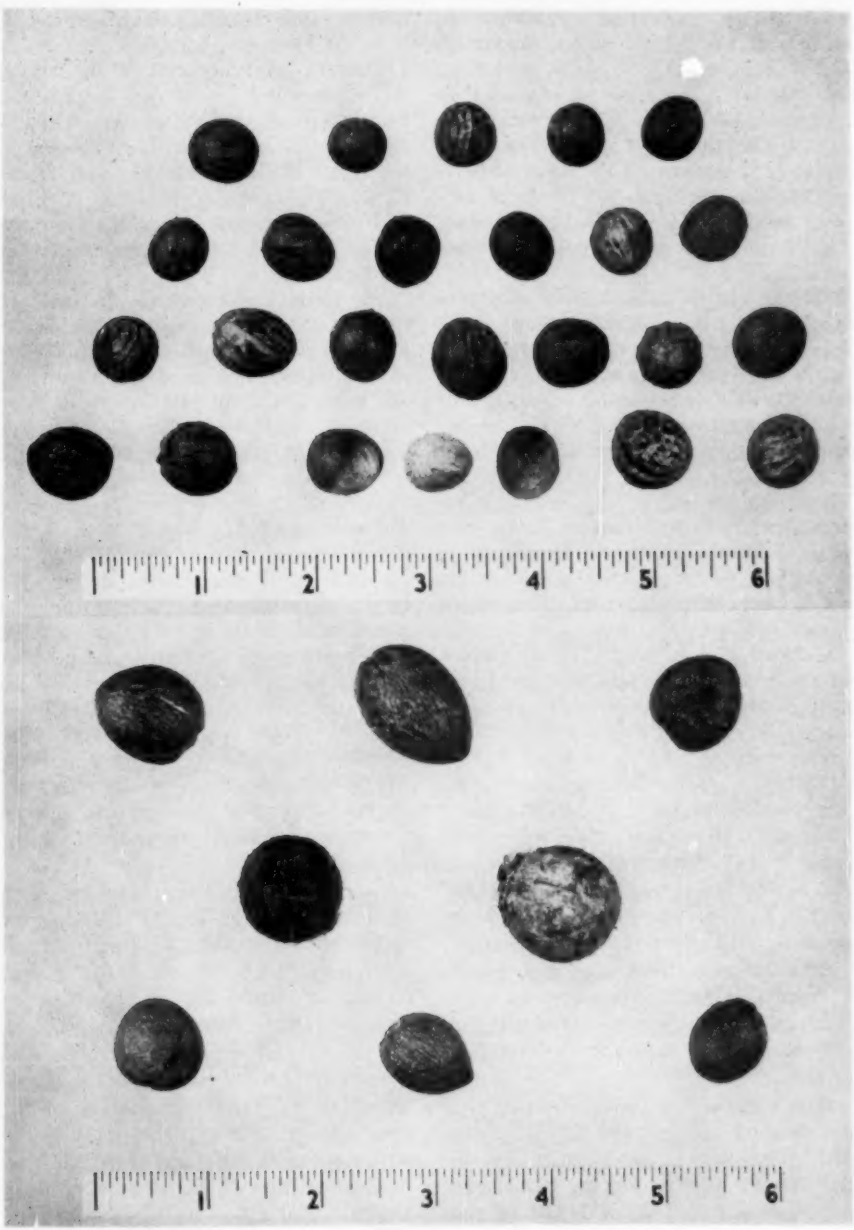

FIG. 19 (Upper). Ucuhuba seed or nuts (*Virola Surinamensis* or *Virola sebifera*).
FIG. 20 (Lower). Tucum seed or nuts (*Astrocaryum vulgare*). Amazon valley.

oil from the fruit of this palm by the simple process of macerating and boiling it with water. There is no known commercial production of the oil in Venezuela, but in Brazil production began in the late 1930's when about 14 m. tons were exported. By 1944 exports reached 215 m. tons, but by 1949 they were less than 25 tons, and today practically the whole production is consumed locally.

Production of patauá oil is most desirable in the Amazon Valley where liquid oils must be imported from the south of Brazil because of lack of other adapted or native oil plants which produce oils of this type. Despite the excellent quality of, and good demand for, patauá oil, its production remains insignificant because of the lack of labor to collect the fruit from scattered wild trees. On the other hand, plantation cultivation of the palm does not appear to be economically feasible because of the relatively low oil content of the pulp (18–24%) and the very low oil content of the kernels (less than 1%) compared to the African oilpalm (pulp, 44–73%; kernel, 42–49%) which probably would grow well in the same area.

Licurí. The licurí or ouricury palm (*Syagrus coronata* (Mart.) Becc.), found on relatively poor dry soil from Pernambuco to Minas Gerais but particularly in Bahia, has been exploited for oil and wax. The kernels were first exploited commercially about 1915, but during the 1930's the leaves of this palm began to be exploited as a source of wax. The wax is now in far more demand and considerably higher priced than the kernels or the oil.

The kernels were formerly exported to France and later to the United States, but so far as is known none is exported at present. Production of kernels has declined from a peak of 14,891 m. tons in 1942 to less than 3,000 tons in recent years. The principal use of the oil, like that of other Brazilian palm kernel oils, is in the local soap industry.

Pracaxí. A semi-solid fat known as "pracaxi" or "pracachy" is obtained from the seeds of *Pentaclethra filamentosa* Benth., one of the Leguminosae in the North of Brazil, Venezuela, the Guianas, Trinidad and parts of Central America. In Brazil it abounds along the humid river banks and low islands of the Amazon.

The seeds, which are borne in pods, are flat and slightly oval-shaped, and when air-dried consist of 10% shell and 90% kernel. The whole seed contains 45%, the kernel 51%, of oil. At room temperature the oil is a dark yellow liquid in which white granular particles of solid fat are suspended.

The oil has never been thoroughly examined, and only a few of the usual characteristics have been determined. Its fatty acid composition appears to be unknown, although the literature has several statements to the effect that the oil contains both saturated and unsaturated acids with chain lengths in excess of 18 carbon atoms. The oil of the seeds from the closely related *P. macrophylla*, which is found in both East and West Africa as well as Brazil, has been shown to contain C_{20}-, C_{22}- and C_{24}-acids, amounting to 20.7% of the total fatty acids.

Small quantities of pracaxi oil have been produced sporadically at Belém; for example, 13 and 34 m. tons in 1937 and 1938, respectively. It was reported that 53 m. tons of this oil were shipped to the United States in 1941, and in 1950 that the States of Pará and Maranhão and the Territory of Amapá produced 213 m. tons; but no production was recorded from Pará in 1951 or 1952. In 1954 the writer saw a small quantity of this seed in the seedhouse of one of the oil mills in Belém. The oil is no longer exported and such small amounts as are produced are used in the domestic soap industry.

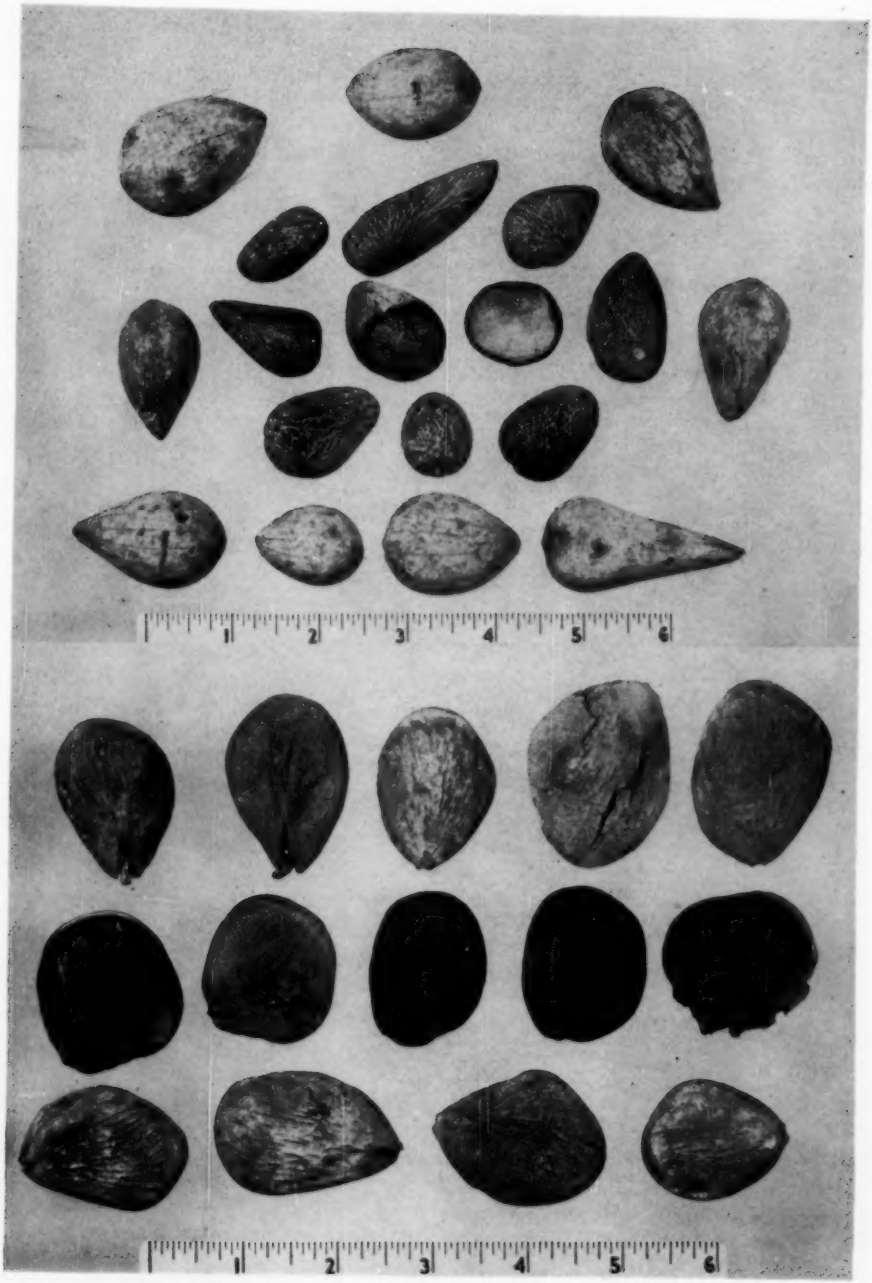

FIG. 21 (Upper). Murumuru seed or nuts (*Astrocaryum murumuru*). Amazon valley.
FIG. 22 (Lower). Pracaxi seed or nuts (*Pentaclethra filamentosa*). Amazon valley.

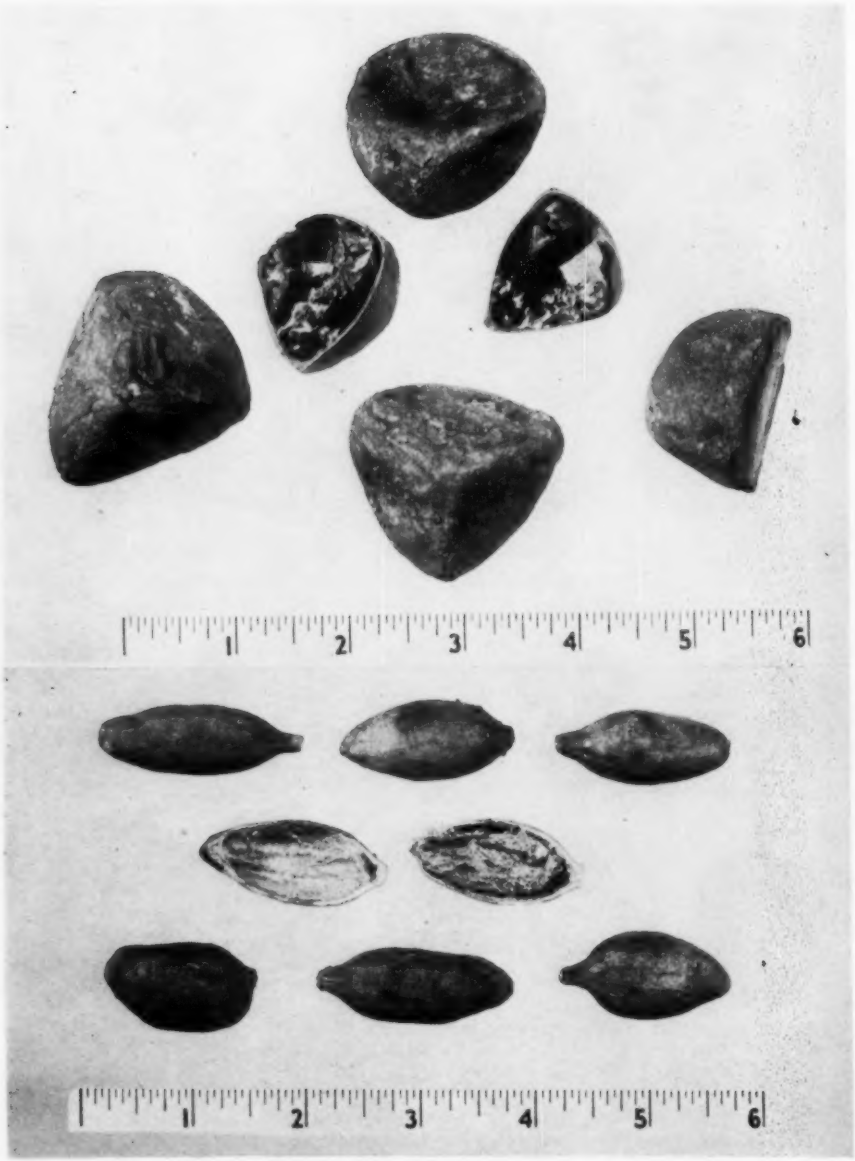

FIG. 23 (Upper). Andiroba seed or nuts (*Carapa guianensis*). Amazon valley.
FIG. 24 (Lower). Oiticica seed (*Licania rigida*). State of Ceará.

Curuá. The curuá palm (*Orbignya spectabilis* or *Attalea spectabilis*), abundant in Pará and elsewhere in northern South America, yields a kernel oil similar in composition and use to other South American palm kernel oils. During the 1930's small quantities (up to 40 tons) of this oil were produced in Pará. It was reported that in 1945 there were produced 222 tons of this oil, but by 1951 no production was given from Pará. It has been stated that efforts have been made to place this palm in plantation cultivation, but, since the fruit contains an average of only 8% oil, its cultivation would not be economical.

Andiroba. Andiroba or carapa oil, known in the United States as "crabwood oil", is obtained by pressing the kernels from the nuts of *Carapa guianensis* Aubl., a giant tree of the mahogany family, which is found on many islands at the mouth of the Amazon River and in areas around the mouth of the Tocantins River in Pará. Other species of this genus occur elsewhere in northern South America, the West Indies and West Africa. The large spherical fruit consists of a woody capsule containing several triangular-sided seeds weighing about 15 grams each. The kernels represent about 75% of the weight

FIG. 25. Babassu kernels (*Orbignya speciosa*). State of Maranhão.

of the seed and contain about 60% fat. Both the seed and oil have a bitter taste. The semi-solid fat, which contains 19% myristic and 13% palmitic acid, is used as a soap oil.

Between 1935 and 1940 production of andiroba oil varied between 200 and 400 m. tons, all except a few tons from the State of Pará. Production in 1950 was 213 m. tons; in 1951 and 1952 production in the State of Pará was 205 and 115 m. tons, respectively. Small amounts of this oil were exported to Europe and the United States between 1935 and 1945, but since then exports have practically ceased, owing to domestic demand and declining production.

Processing Facilities

Brazil is well supplied with facilities for processing seed, refining oil and manufacturing finished products. On December 31, 1952, the country possessed 369 establishments, representing an investment of more than one billion cruzeiros and employing more than 17,000 individuals engaged in the production of glyceride and essential oils. Eighteen States and the Federal District were reported as having oil mills, and only two States and five Territories as having no mills. Of the total mills, 262 were in seven States [6]. Some of these mills are quite large and well equipped, and process a variety of seeds; some process both glyceride and essential oils, while others handle only one or the other.

According to the 1950 census, there were 66 cottonseed oil mills; 157 mills engaged in processing a variety of oilseeds for the production of edible, soap and industrial oils, including peanut, castor, oiticica, linseed, tung, babaçú, dendê, coconut and other palm oils; 37 plants producing inedible tallows and greases, fish oil, glycerine, casein and glue; and 56 mills engaged in extracting essential oils (laurel, geranium, rosewood, sassafras, copaiba, eucalyptus, chenopodium, etc.). There were also reported 642 soap factories, 79 candle factories, and 116 establishments manufacturing a wide variety of protective and decorative coatings (paints, varnishes, enamels and related products). Fifteen establishments were reported to be producing refined oils, and six producing margarine, compound cooking fats and related products.

In general, there exists a large excess of oil mill capacity in comparison to the amount of available raw material. For this reason considerable processing capacity is idle for much of each crop year. Even though the processing capacity were only equal to the volume of raw material available during normal crop years, the mills would have to expect varying periods of idleness, owing to prolonged periodic draughts, breakdowns in rail transport between the interior and the oil mill centers, and in some cases inadequate storage capacity for oil or seed. Some oil mills, especially in the North and Northeast, have been presented an increasingly serious problem because of the decline in collection of nuts and seeds from wild palms and other indigenous plants. In some cases well-equipped mills are being allowed to deteriorate or have been offered for sale because operations have become so limited as to be unprofitable. Despite the existence of considerable oil mill capacity, new mills continue to be planned and built. Some of these, like the new solvent extraction plant for soybeans in Porto Alegre, are rationally planned and fulfill a distinct need. Others proposed have been ill conceived and can result only in financial loss.

The distribution of Brazil's vegetable oil mills follows a pattern dictated by climate and geography, the former of which governs the types of oilseeds avail-

[6] São Paulo, 55; Rio Grande do Sul, 43; Santa Catarina, 40; Pará, 40; Amazonas, 34; Ceará, 27; Bahia, 23.

able for processing, the latter the system of transport, distribution and consumption of the end products.

Most of Brazil's population is concentrated in a relatively narrow belt along its more than 3,000-mile long coast, and is centered around the capital and/or port cities. Most of the railways and, until recently, highways extended westward into the interior from these centers, whereas the North-South transport and communication between these centers were by way of the sea.

The largest cities and densest population extend from Rio de Janeiro southward to Porto Alegre. This part of Brazil is also the principal manufacturing area, whereas the North and Northeast are the sources of much raw material. It was, therefore, common practice to ship raw materials (oilseeds and crude oil) from the North by coastal vessel to the South and to return part of these materials in the form of finished products by the same means. In the past it was often necessary or more eco-

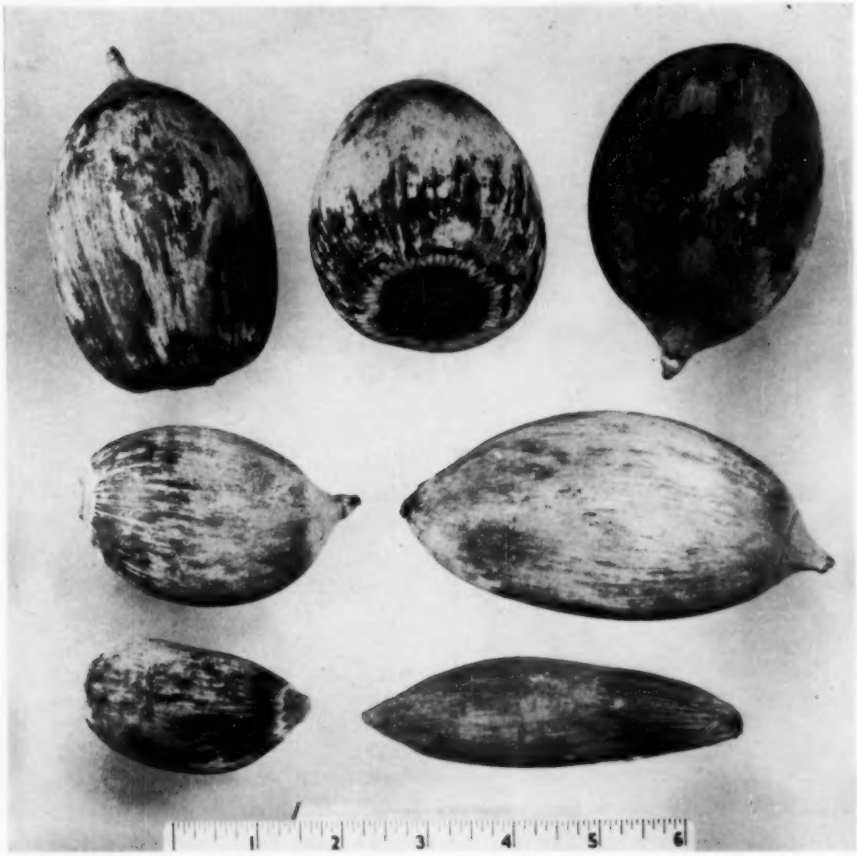

FIG. 26. Babassu fruit or nuts (*Orbignya speciosa*). State of Maranhão.

nomical to ship the raw materials to the United States or Europe because of lack of sufficient market in the South or because the products brought a better price in the world market than in the Brazilian market.

FIG. 27. Breaking babassu fruit prior to extracting kernels. The little girl can produce three kg. (6.5 lbs.) of kernels per day, the boy one kg. (2.2 lbs.) Kernels are worth about four cents per lb. at point of production. State of Piauí.

For the most part, northern and southern Brazil produce different types of oil-bearing materials. The North yields babaçú, murumuru, tucumã, ucuhuba, dendê, cashew, oiticica, pracaxi and many other seeds and nuts from wild plants; castor, cottonseed from mocó or tree cotton, etc. The South yields cottonseed from Upland cotton, peanuts, sunflower-seed, sesame, soybeans, corn germs and small amounts of linseed and tung. In other words, the North produces the raw materials for soap and industrial oils, and the South the raw materials for edible oils.

In general, the largest oilmills, refin-

eries, margarine and shortening plants, soap factories, paint mills and other finished products plants are concentrated in the South close to the largest consuming centers and where inland transportation (rail and highway) is most highly developed. In the North the oil mills are smaller, process less diversified oil-bearing materials, and often do no refining or manufacture of finished products. During the period under review some of the northern oil mills began to refine oils, to produce toilet soaps and to distill fatty acids and other types of products to satisfy the expanding markets in the North and thus avoid or reduce the long transport of raw materials and finished products between the North and South. This has led to some over-expansion in the North, which has been aggravated recently by the decline in volume of available raw materials in the area.

FIG. 28. Babassu palm with fruit and bracts from which mature fruit has fallen.

Discussion and Conclusion

Fifteen years ago Brazil was classed as one of the few surplus fat areas of Latin America; it exported a variety of oleaginous materials in the form of seeds and oil. Principal among these were castor, babaçú and cottonseed, and a large number of minor oil-bearing seeds and nuts were also shipped abroad.

In recent years the only one of these products to be exported in appreciable volume has been castor in the form of both seed and oil, which, on an oil equivalent basis, amounted to 42,804 m. tons in 1954. In the past three or four years appreciable quantities of soybeans have been exported. In 1954 the export of this oilseed was equal to 3,802 m. tons of oil. A large solvent extraction plant for processing soybeans is under erection in Rio Grande do Sul, which when completed will result in the curtailment or complete cessation of these exports. The only other exports in 1954 were 5,186 m. tons of oiticica oil and 51 m. tons of oil and oil equivalent babaçú kernels, and 23 tons of unidentified miscellaneous oilseeds. Thus total exports of oil and oil-equivalent seed in 1954 amounted to only 51,843 m. tons, of which castor accounted for 83%.

In contrast to exports, Brazil imported during the same year 31,073 m. tons of oil or oil equivalent seed, principally for edible use. Olive oil (15,279 m. tons) and lard (10,470 m. tons) accounted for 83% of the total. It was, however, necessary to import 2,086 tons of palm (dendê) oil for the manufacture of tinplate, which accounted for an additional 6.7%.

According to data published in the Anuário Estatístico do Brasil, 1954, the estimated population of Brazil, as of July 1, increased from 41,144,000 in 1940 to 57,226,000 in 1954, or an increase of

FIG. 29. Tucum palm (*Astrocaryum vulgare* Mart.). State of Maranhão.

39%. According to a report of the United Nations, it is anticipated that the population of Brazil will be doubled within 30 years and in any event will exceed 100 million [7].

It can be expected that Brazil's fat and oil requirements for food and industrial use will expand at a more rapid rate during the next few decades than in the period under review. The increased demand will exceed the rate of population growth because of the increasing urbanization and industrial development, and the increase in per capita purchasing power which will accompany these tendencies.

During the period 1940–54 the continually increasing domestic demand for fats and oils was satisfied largely by the almost complete cessation of exports of oils and oilseeds normally intended for edible consumption and the manufacture of soap, and by importation of increasingly larger quantities of edible oils, and

[7] On January 1, 1955, the population of Brazil was officially estimated to be 57,924,887.

palm oil for use in the manufacture of tinplate.

If the volume of production of these commodities is inadequate to meet the present demands, what are the expectations of filling the even greater demands of the next 25 to 30 years? In view of Brazil's foreign exchange position it is unlikely that imports of fats can be increased. It is equally unlikely that the production of cottonseed oil can be augmented because of lack of market for fiber. It is becoming increasingly evident that the production of the so-called extractive oils (babaçú and other palm oils, and oils from other wild plants) will decline instead of increase because of lack of labor to collect the seeds and nuts in the principal areas where the plants abound.

The deficit in edible oils can probably be overcome by increased production of peanuts and soybeans and possibly of olives which are presently being planted in the South of Brazil, but the problem of a supply of soap and tinplate oils is more difficult. A large-scale domestic coconut oil industry seems unlikely in view of the demand for fresh coconut and the high cost of producing copra under Brazilian conditions. The only solution to the constantly increasing demand for soap and tinplate oils appears to be the introduction of a plantation system of growing the African oilpalm. Experiments to date in Bahia do not appear very encouraging, but there remains the possibility of development in the Amazon region which probably has soils and adequate rainfall for optimum growth of this palm. Even this potential has not been adequately explored, and it will take many years to develop a coordinated plantation–oil mill system, even if the operation proves to be feasible.

With respect to industrial oils, Brazil seems to face a brighter future so far as domestic supplies are concerned. Production of castor and oiticica oils and cashew shell liquid is adequate to take care of foreseeable domestic demand for a number of years. The production of tung and linseed oils can be increased, provided only that the farm price of these oilseeds is increased. However, increased domestic consumption of castor and oiticica oils and of cashew shell liquid must be at the expense of exports of these commodities to the United States, for it is unlikely that supplies of the raw materials of these oils will be markedly increased.

It seems amply evident from the foregoing review of the trends in the fat and oil economy of Brazil that immediate and strenuous efforts must be initiated to increase the production of some types of these commodities to avoid a further lowering of the nutrition of the people and producing adverse industrial and economic effects.

Food From Fungi

If and when economic conditions and technological advances become favorable, fungi may some day be significant in furnishing human food through their protein-synthesizing capacity. The yeast, Torulopsis, has already been utilized on a commercial scale in this direction in Germany, Jamaica, South Africa, India, California and Wisconsin.

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Introduction

An abundant food supply is a country's most precious asset. In addition to being sufficient to support the population during normal times, it must provide a surplus for storage to carry the population through periods of possible crop failure and provide reserves in case of war or other world catastrophe. It is also desirable to have substantial amounts for export to countries where sufficient food cannot be grown.

The specter of possible eventual world-wide famine was first presented by Robert Malthus in the eighteenth century. Since that time the neo-Malthusians and their opponents have been engaged in bitter verbal warfare concerning the possible Armageddon between human fecundity and the ability of the world to produce food.

There probably never has been a time when some portion of the world's population was not hungry. Famines occurred in India and China long before North America, Argentina and the Antipodes, the bread baskets of the world, were even settled. We learn of the famines of Egypt through biblical history. Eskimos, some Indian tribes and other primitive peoples have always lived under the shadow of the rider of the black horse of the Apocalypse. On the other hand, a few parts of the world after agricultural development have almost always been fortunate enough to produce a food surplus. In most countries there is barely sufficient.

How, then, can the world's people best be fed at their present rate of increase? The ideal solution to the problem, of course, would be to control the world's population at or slightly above its present level without the aid of famine, war or pestilence, but such a desirable solution obviously is not possible. Nor is it possible to operate the planet as an ecological unit. The Food and Agricultural Organization of the United Nations performs a useful function by making itself a kind of world center for international nutritional hopes. Currently the F.A.O. is attempting to increase world production of fertilizers and to rationalize their distribution among its member countries. Its fertilizer target for 1960 requires almost tripling our present production of nitrogen and doubling our production of phosphate and potash. Such a rationalization of the world's food, presupposing corrosion of the iron curtain, would, of course, intensify the problem of producing enough food for all in the future.

Previous challenges of an increasing global population have been met by opening new land areas to cultivation and by increasing agricultural efficiency. However, even the most unobserving can see that such sources are not limitless. Other food supplies must be developed. The best possibilities seem to be new

foods, food from the sea, and foods from industrial wastes or from materials such as wood, which in themselves are not edible but may be made so by chemical or biological means. The use of fungi as food or in the production of food is practically an undeveloped resource but seems to be one on which we could depend greatly in the future.

Present Potential of Food Production

Sir John Russell and many other modern-day scientists agree that the food needed for at least half a century to come can be supplied by using conventional methods. Of the undeveloped resources, 0.6 percent of the world's land, reclaimed by irrigation, feeds 25 percent of the world's people. Vast areas of unproductive land throughout the world, if irrigated, could raise food production far above present levels.

Charles E. Kellogg, Chief of the Division of Soil Survey of the United States Department of Agriculture, points out that, given the will to use it, the world at the present time does not lack productive land, although some areas have been over-populated for centuries. By extending our agriculture into the cool temperature areas of North America and northern Eurasia, we could bring into use 300 million acres of new arable land. In addition, there are the barely touched soils of tropical Africa, South America, Central America, southeastern Asia and the Pacific Islands. If only 20 percent of these soils were brought into cultivation, a billion acres might be added. We may not need them for some time—not all of them at least—if we achieve the 20 percent average increase in the production of land already under cultivation that United States Department of Agriculture experts consider entirely practicable.

Modern science has not only increased greatly the efficiency of our agriculture, but continues to do so at an accelerated rate. Between 1800 and 1900, the number of man-hours required to produce 100 bushels of wheat dropped from 373 to 47. New corn hybrids have boosted yields from 22 bushels to as much as 125 bushels per acre. In 1820 one farm worker supported about 4.5 other people; by 1946 this figure reached 14.5, and today is even higher. In other words, less than 50 percent of our farmers raise 90 percent of our food. Even their output could be greatly improved by the full use of existing agricultural science, not counting that of the future, and if the remaining majority of farmers were to do no more than follow the example of our better farmers, food production from conventional methods could be raised far above present levels.

Of the present fish crop of 37 billion pounds per year, 98 percent comes from the waters of the Northern Hemisphere. Only a small percentage of the edible fish in this territory is actually used. The remainder are discarded or used for fertilizer. The far more extensive waters of the Southern Hemisphere, although perhaps not so favored with shallow fishing grounds such as the Newfoundland Banks or the North Sea of the Northern Hemisphere, nevertheless, could contribute an enormous additional amount of protein and fat. Fish farming as practiced in India, China and Japan produces four to eight tons of protein food per acre per year—far more than any other form of animal husbandry. Fish farming could be practiced much more widely.

Kellogg states, however, that such estimates of potential food production are very optimistic in one sense and probably still too low in another. They indicate only what might be done with present knowledge if the political and economical barriers to effective soil use were somehow removed. Although we can see ahead clearly for a few years with regard to the world's food supply,

we shall not be able to depend entirely on conventional foods and agricultural methods for our future unquestioned population increase. Additional types of food and other methods must be developed to meet the challenge.

It is not expected that this development will occur suddenly. Instead, with gradual decrease in our remaining land reserve and leveling of our agricultural efficiency curve, we shall probably begrudgingly learn to utilize the new types of food.

Possible Future Sources of Food

The additional types of food most frequently mentioned in the writings of scientists interested in peering into the nutritional future are those from fresh-water and marine planktons, those from the larger marine algae, and those from various fungi. In laboratories all over the world during the past few years, scientists have been experimenting with fresh-water plankton algae, notably *Chlorella*, as a source of food. Such algae are rich in proteins and vitamins. If produced in quantity, and the prejudice to a new produce be overcome, the dried algae would provide an important source of food. A few pilot-plant installations have shown that it is possible to cultivate the algae in amounts large enough to be used for human or stock food, and a few enthusiasts talk about installations capable of producing ten million pounds a year, to be located in areas such as India, Japan or Israel.

The practicality of such installations is yet to be demonstrated. We remember the early enthusiasm with which hydroponic farming was first promoted. Today hydroponic plant culture is practiced only in some floriculture establishments and in a few locations where tillable soil is not available or is too contaminated for safe cultivation of fresh vegetables. The method just could not compete economically with standard farm practices.

Fresh-water algal culture is handicapped by several of the same factors that make hydroponic plant culture expensive, for example: high cost of equipment and nutrient chemicals, the need for great care in preventing contamination, and high labor and maintenance cost per unit of production. In addition the location of suitable installations would be limited to warm, sunny, semi-desert areas. On the other hand, if costs could be reduced by developing a method whereby the algae could be grown in ponds instead of in tanks or plastic tubing, or if sewage wastes could be used to provide the required nutrients, the utilization of fresh-water plankton algae could become more practical.

Ocean plankton has long been considered a potential source of human and animal food. The supply is inexhaustible and it is available for the gathering. The blue whale, the largest of animals, lives on plankton organisms which it obtains by straining them from the water, using its specially adapted mouth parts. Dr. Cyril E. Lucas of the Marine Laboratory at Aberdeen, Scotland, estimates that the English Channel is capable of producing two or three tons of plankton per acre per year—equal to an average cereal crop over an equivalent area—and the potential yield of Arctic waters is even greater.

However, the only commercial harvesting of marine plankton is by Thailand which obtains about 5,000 tons a year from the adjacent seas. Japan and Israel are said to have experimental installations. For a short time, plankton was fed to leprosy patients in Venezuela, not for its food value but because of its vitamin A content. Marine plankton, because of its food potential, ease of access and inexhaustible nature, offers a substantial future food supply.

Non-plankton marine algae, or sea-

weeds, are gathered both for fertilizer and for food in many parts of the world. A number of species form the basis of small business enterprises which produce colloids for the pharmaceutical and food industries. Marine algae have always been a very important part of the food of the Japanese people. The hitherto almost national diet of Japan, consisting of rice, fish and seaweed, may have had much to do with the general good health of the nation as a whole. At present, few other nations make full use of their marine algae resources; they may be compelled to do so in the future. Unfortunately the non-plankton algae, with the exception of a few floating forms, are almost entirely confined to the littoral area of the oceans. Such areas cannot be enlarged for algal production, and so future food from this source will be more limited than that from plankton algae.

The fungi offer one of the best future sources of food, partly because they can produce it in a much shorter period of time than can the higher forms of green plants. Fungi, since they have no chlorophyll, cannot synthesize food from the basic elements and compounds, but many can produce edible materials from inedible wastes. In addition, fungi do not require light for energy, and often can be adapted to the efficiency of submerged culture. Unlike green plants in the manufacture of food, fungi can work 24 hours a day every day to produce edible material from wood, sewage, industrial wastes or almost anything of an organic nature. This great potential will be unfolded in the following sections.

Efficiency in Food Production

A sufficient caloric intake does not guarantee a good standard of nutrition. Food containing minerals, vitamins and enough of the right kind of protein is necessary in addition to that furnishing energy.

At one time all protein was considered to be of equal nutritive value. As knowledge of the chemical constitution of proteins unfolded, however, the emphasis shifted from general protein requirements to the requirements for specific amino acid constituents. These requirements differ with different animals. The adult human being, for example, requires eight amino acids for maintenance of nitrogen equilibrium (Rose, 1949). If all of these are provided in suitable amounts, the body can form from them the remaining amino acids which enter into the composition of its proteins.

In cattle and sheep, any dietary need for specific amino acids is of markedly less importance because of their synthesis in the rumen. Herbivorous animals can do very well on diets that contain plant proteins only, and ruminants can even replace in part plant proteins with urea because of the efficiency of the rumen bacteria. Man and carnivorous animals, however, need animal protein, or protein from animal products, to supplement their supply of plant protein.

Our present conventional method of converting carbohydrates and plant proteins into animal protein is not an efficient process. The animals we use for producing proteins convert only 10 to 25 percent of their feed into human food. Microorganisms are much more efficient in manufacturing protein food and can use wastes and surplus materials not suitable even for animal feed.

Fungi can be produced in quantity within a few hours or days. Their efficiency in protein production from a given quantity of carbohydrates is about 65 percent in comparison with about 20 percent for pork, 15 percent for milk, five percent for poultry, and four percent for beef. The produce of an acre of land can be transformed into ten times as much fungus protein as meat protein.

A steer weighing approximately half a ton produces protein at the rate of 0.9 pound per day. If one-half ton of soybeans under the most favorable conditions be planted and grown, and the beans harvested and processed, their average yield, calculated on a 24-hour basis, would be 82 pounds. But if half a ton of *Torulopsis*, the type of yeast frequently used in protein synthesis, be grown under favorable and technically possible conditions, then 51 tons of protein would be synthesized in 24 hours (Thaysen, 1953). Even more important is the fact that many fungal proteins are surprisingly similar to those produced by animals, which makes them especially useful as supplements to cereals.

Utilization of Waste Products

Many believe that one answer to an increasing population is to be found in the better use of the vast food energy supply we have at present. Large quantities of food materials are discarded as waste because they are not in a form suitable for human consumption. Concentrated effort in utilizing the present available food energy from such wastes could produce as much or more than long-term developments to utilize our natural energy resources. The use of molds and other microorganisms appears to be an efficient method of doing this.

One great advantage of the use of fungi as food lies in the fact that they can be grown in large masses on cheap carbohydrate materials such as molasses (Basaca, 1953), potato and other vegetable wastes (Reiser, 1954), and even waste sulfite liquor from the wood-pulping industry (Wiley et al., 1951). Other fungi are being used in the brewing and distilling industry; still others have been developed for the production of fats, enzymes, organic acids and other industrial products. It has been estimated that one acre of concrete-enclosed pond used for the propagation of fungi or algae could produce fat equivalent to that yielded by 25 acres of a vegetable oil crop.

The idea of fermenting industrial and agricultural wastes is not new. Work has been done on the production of alcohol from nearly every waste carbohydrate product that occurs in large enough quantity to make its utilization attractive. A partial list of the materials that have been used in this manner would include lumber waste, cannery and dairy by-products, pulp mill waste, starchy grains, straw, by-products of the sugar industry, brewery waste, waste liquor of the clothing industry, and grain hulls.

Each of the above categories could be broken down further. The general idea is that any waste which contains carbohydrates in concentrations of three percent or more can be fermented economically, barring the presence of toxic material.

Considerable research on fungal disintegration of wood has been carried on by the wood industry in the United States. This industry has concentrated on using only wood waste, and the fungus proteins obtained were used for animal food. Wood waste and other waste vegetation represent the world's greatest untapped resource of organic material. From wood waste can be obtained sugars which may be used as substrates for fermentation or the growth of fungi. Notable among the industrial processes which have been developed for converting wood waste to sugars are those of Scholler and Bergius. Both of these processes produce fermentable sugars from wood chips, making them available for utilization by the yeast *Torulopsis utilis*. The efficiency of the Scholler process is said to be 14 kg. of yeast obtained per 100 kg. of dry wood used. Approximately two-thirds of the nitrogen (added as ammonium hydroxide) is recovered as yeast protein. Zellstofffabrik Waldhof

developed a continuous process for growing torula yeasts on waste sulfite liquor.

In view of such processes, many ask, "Why could not a process be developed that would make the production of good high-protein food for human consumption from waste products economically feasible?"

The unmodified dried yeast produced by the Scholler and Bergius techniques is too bitter to be palatable; but yeasts can be debittered, or more bland forms found. A tasty yeast extract has been prepared, flavored with onions, celery, parsley or carrots, and marketed as a paste. Thus formulated, such yeast proteins, although not a balanced food, are acceptable when used with other proteins. The practical use of wood conversion is limited by the low cost of competing carbohydrates, but the economics in favor of wood conversion are constantly improving.

During World War I, the Germans grew yeast as a source of dietary protein. The project did not meet with striking success, however, because the amounts fed were too large to be well tolerated. During the winter of 1940–41, when Britain's food situation was perilous, considerable attention was given to the use of yeast for the purpose of supplying part of the protein customarily obtained from meat.

At present a number of factories are producing food yeast. Among the first were those set up in Jamaica and in Durban, South Africa, localities where there is a shortage of protein food and an abundance of blackstrap molasses. The molasses is fermented with *Torulopsis utilis* and the yeast recovered as the dried flake product. A small molasses-based plant is run by the Albers Milling Company in California, but its output goes entirely into poultry feed.

The Sulfite Pulp Manufacturer's Research League adapted the Waldhof process for its pilot plant which was the basis for Lake States Yeast Corporation's Rhinelander, Wisconsin, plant started in 1948. SPMRL was organized in 1939 to study means of utilizing by-products of member mills and thereby cut down stream pollution. Post-war information on German technology brought about the adoption of the Waldhof process.

A *Torula* yeast plant for the Charmin Paper Mills was scheduled to open recently, and it was expected that at least 20 percent of the output could be used for human food.

In Germany over a dozen plants were in various stages of construction and operation at the close of the war. The Mannheim plant of Zellstofffabrik Waldhof has been in more or less continuous production since 1941. Several plants put in standby at the end of the war are beginning to come back into production (Anon., 1955).

There are also plants in Switzerland, France and Sweden, and probably in areas within the Soviet orbit. On Formosa the Chinese Nationalists have started construction of a very large torula yeast plant. It is being built with United States technical assistance and will use molasses to produce an expected 40 metric tons of yeast per day.

In India several tons of United States–produced *Torula* yeast have been subjected to nutritional trials within the past year. The situation in India is particularly favorable for the development of the food yeast industry. Over 300,000,000 people there do not eat meat, and India has the largest sugar industry in Asia, which would provide the necessary carbohydrate energy for the yeast.

The peoples of Latin America could also benefit by addition of cultured yeast to their diet, now composed largely of beans and corn which do not furnish proteins of good quality. Throughout the world the nutritional status of countless people living on low-income levels

could be improved in a short time by the development of cultured food yeast industries using waste carbohydrates.

Value of Fungi as Food

A comparison of reports on the composition and nutritive properties of fungi presents a rather confused picture. This is due in part to the fact that many types of fungi are reported under a common heading with little or no regard for species differences. One of the more careful analyses of the cultivated mushroom (*Agaricus* (*Psalliota*) *campestris*) was conducted by Anderson and Fellers (1942). They found the moisture content to be 89.5 percent; ash, 1.26 percent; protein, 3.94 percent; fat, 0.19 percent; fiber, 1.09 percent; and nitrogen-free extract, 4.01 percent. This analysis is practically identical with that presented in the several manuals on mushroom-growing available today (Kligman, 1950; Rettew, 1948). It is of interest to compare it with analyses obtained by Adriano and his associates (1933) in the Philippines for *Agaricus campestris* and other species and genera (Table I).

The differences in the protein content of the fungi in Table I are somewhat misleading, since the tabulation was made on a fresh weight basis and the moisture content varied from less than one percent in woody *Lentinus* to more than 90 percent in the watery *Hirneola* and *Auricularia*, both of which are fleshy fungi but not mushrooms. The percent of protein when calculated on the dry basis shows considerably less variation and indicates that the food value of most fleshy fungi is similar to that of fresh fruit and vegetables.

The mineral content is somewhat higher for fleshy fungi than it is in many fruits and vegetables. From an analysis of several fungus species (Table II) it is evident that potassium, sodium and

TABLE I

FOOD VALUE OF MUSHROOMS

	Percentage fresh basis						Value per kg. dry weight	
					Carbohydrates			
	Moisture	Ash	Protein (N × 6.25)	Fats (ether ext.)	Crude fiber	N.F.E.	Calorific	Protein
Agaricus campestris (canned in France)	92.58	1.38	4.63	0.03	0.92	0.46	211	62.40
A. campestris (Philippine var.)	78.30	1.66	10.13	1.37	2.02	6.52	810	46.68
A. merrillii Copel. B.	89.02	1.09	5.36	0.17	0.76	3.60	383	48.85
A. perfuscus Copel.	90.06	1.02	4.71	0.20	1.04	2.43	311	50.10
Auricularia auricula-judae	16.40	7.87	9.69	1.22	5.79	59.03	2931	11.59
Auricularia sp.	89.07	0.51	0.66	0.91	2.16	6.69	386	6.04
Hirneola affinis	98.02	0.22	0.19	.27	0.23	1.07	77	9.60
Collybia albuminosa	89.93	0.79	2.96	.40	0.81	5.11	368	6.28
Auricularia polytricha	90.45	0.57	0.60	.93	1.14	6.31	370	29.44
Collybia sp.	95.18	1.24	0.32	0.20	0.69	2.37	129	6.72
Cortinellus sp. (from China)	19.49	4.87	20.82	2.36	10.89	40.57	2777	27.10
C. shiitake (from Japan)	18.37	5.30	15.29	0.97	12.02	48.05	2687	18.73
Lepiota cepaestipes (poisonous, French)	79.19	2.02	4.81	.60	2.41	10.97	703	23.11
L. chlorospora (poisonous, French)	91.32	1.08	4.38	.10	0.79	2.33	284	50.41
Lentinus squarrosulus	70.77	1.56	2.44	.99	6.33	17.91	926	8.75
L. exiles	71.71	1.20	4.52	.60	9.19	12.78	765	15.97
Pleurotus ostreatus	10.65	5.88	12.04	.86	7.44	63.13	3162	13.48
Lentinus sp.	61.88	0.97	1.56	.05	0.86	2.65	154	18.75
Marasmius sp.	9.35	1.55	3.09	.76	1.99	3.26	331	29.06
Lentinus sp.	0.26	1.13	3.57	0.40	3.39	11.25	645	18.09

TABLE II

INORGANIC CONSTITUENTS OF MUSHROOMS BASED ON ASH

	Ash-dry basis	Percentage of inorganic constituents of ash										
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	P_2O_5	S	Cl	Total
Collybia albuminosa	7.85	14.34	7.10	0.95	3.86	5.04	9.10	17.33	39.95	1.35	Trace	98.99
Volvaria esculenta	13.20	15.23	4.47	0.99	2.35	0.92	15.37	24.76	30.14	1.42	3.85	99.50
Lycoperdon lilacinum	7.73	5.85	1.50	1.19	1.76	1.61	9.46	29.29	48.01	0.62	Trace	99.28
Cortinellus shiitake	6.05	9.28	5.69	0.71	2.73	6.77	24.04	24.82	19.07	3.91	1.20	98.22
Cortinellus sp. (China) ..	6.49	15.17	6.07	0.33	3.59	7.05	21.17	27.37	16.41	2.21	Trace	99.37
Lentinus exilis	5.24	11.07	6.44	0.75	3.51	1.89	21.38	29.65	22.45	1.19	"	98.13
Auricularia sp.	4.67	9.04	12.65	2.33	11.05	7.97	6.62	17.77	29.89	2.17	"	99.09
Agaricus campestris (France)	18.60	8.96	7.91	6.22	3.11	0.89	42.58	4.02	8.22	2.08	....	....
Pholiota sp.	12.59	4.01	4.01	9.73	12.43	1.02	23.64	5.44	33.04	2.03	2.74	98.09
Lepiota chlorospora (poisonous)	12.44	3.35	14.88	10.05	4.19	1.52	20.40	6.98	33.19	2.53	1.15	98.24
L. caepestipes (poisonous)	9.71	0.92	9.61	5.03	0.91	3.14	13.59	27.49	33.19	2.51	....	....
Marasmius (looks like *M. oreades*)	14.55	16.24	7.91	3.71	3.09	1.35	20.30	21.50	22.75	1.95	1.57	100.37
A. campestris (Philippine var.)	9.93	2.52	5.84	1.84	6.14	0.67	33.21	14.62	27.33	1.39	6.45	100.01
Lentinus sp.	5.72	14.41	8.66	13.88	2.11	2.94	6.73	18.33	24.77	1.03	....	....

phosphorus salts are the main constituents of the ash, but small amounts of copper and other minerals are also present (Anderson and Fellers, 1942) in fungi. So far as iron is concerned, slightly less than one-third of the total iron is in the available form or in the condition readily utilizable by the human body.

Until quite recently little investigation was conducted on the vitamin content of mushrooms, and some of the results that were obtained were contradictory. Recent more careful analyses show that *Agaricus campestris* is one of the best plant sources of several members of the vitamin B complex. Mushrooms were found to constitute an excellent plant source of riboflavin and niacin, a good source of pantothenic acid, and to contain some thiamin. A prepared serving of a 100-gram portion of fresh mushrooms would provide approximately one-fifth of the adult daily requirement of riboflavin and over one-quarter of the adult daily requirement of niacin. These are the adult daily standards suggested by the Committee on Food and Nutrition, National Research Council, May, 1941. Mushrooms were also found to yield appreciable amounts of ascorbic acid (Kezeli and Dzaparidze, 1944) (Table III) and vitamin K, measurable amounts of vitamin D (Scheunert et al., 1935) (Table IV), but little or no vitamin A or E.

The percentage of digestibility of *Agaricus campestris* protein, as reported by Bohmer (1882), Mornes (1886), Saltet (1885) and Skinner (1933), ranges between 64 and 71 percent. The remaining indigestible nitrogen is probably tied up in glucoseamine, chitosan or chitin. Human feeding experiments performed by Lintzel (1941, 1943) show that the proteins of *Agaricus campestris*, *Cantharellus cibarius*, *Boletus edulis* and *Morchella esculenta* are approximately equal to muscle tissue and vegetable protein in nutritional value.

Mangold (1940, 1941) reported that *Torulopsis* yeast flakes contained 24.5 percent crude protein, which was 70.16 percent digestible by sheep and 64.5 percent digestible by swine. It has been stated, however, by Fink (Irex Com-

TABLE III

VITAMIN-C CONTENT OF VARIOUS MUSHROOMS AND OTHER FLESHY FUNGI

	Mg vitamin C/100 g. (mg.%)					
	Wet weight			Dry weight		
	Basic extract	Acidic extract	Total	Basic extract	Acidic extract	Total
Agaricus (Psalliota) sylvatica	49	4	50	480	40	520
Boletus edulis	31	5	36	215	35	250
Lactarius scrobiculatus	15	18	33	145	170	315
Clavaria botrytis	19	3	22	225	35	260
Lactarius piperatus	20	1	21	195	15	225
Hydnum imbricatum	18	1	19	215	10	225
Cantherellus cibarius	18	1	19	234	9	243
Lepiota procera	18	0	18	120	0	120
Pholiota mutabilis	11	2	13	96	18	114
Lycoperdon gemmatum	5	6	11	51	54	105
Amanita muscarina	7	4	11	81	51	132
Russula incarnata	9	1	10	84	9	93
Clytocybe laccata var. *amethystina*	3	2	5	33	15	48
Russula lilacea	4	2	6	33	15	48

pany, Fulbach, Germany) that an all-yeast protein diet causes damage to the liver in rats because of the low cystine content of *Torulopsis utilis* protein.

As has been stated, proteins differ in quality and are not of equal nutritional value. In actual animal feeding practice and in human nutrition no ration ever contains only one protein but consists of a mixture of many. No ration is ever likely to be entirely lacking in an essential amino acid, but different rations differ widely in the quantitative relations of their amino acids. Thus, subject to variations in digestion and absorption, the ration which has the highest protein quality is the one which supplies all the amino acids needed, in proportions most nearly like those in which they exist in the protein to be formed. Such a ration will meet the protein needs of the body with a minimum intake of food protein and explains why the human diet should contain some meat or animal product.

On the other hand, certain rations may be so deficient in one or more essential amino acids that they will not provide adequate protein nutrition, no matter how much is fed. The amino acids which remain unused in the formation of body protein are not wasted as food because they can serve as a source of energy, but they are wasted as far as the specific function of protein is concerned.

Eight amino acids (isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophane, valine) are considered to be indispensable for man, and, of these, lysine and tryptophane are the ones most frequently deficient in plant proteins.

In Table V, based on data of Horn and associates (1950), it will be observed that the protein of wheat is low in lysine, and that of corn low in both lysine and tryptophane, so that these cereals are a poor source of protein if used alone. It will also be observed that the protein of dried brewer's yeast, used as an example of fungal protein, contains a higher proportion of lysine than is present in milk protein but somewhat less tryptophane. One of the most nutritious proteins from a crop plant, considering its value in replacing animal protein, is that from the soybean which

contains somewhat less lysine than yeast protein but slightly more tryptophane.

The point brought out by this table is that fungal protein, exemplified by yeast, is more nearly like animal protein in its amino acid constituents than is the protein of cereals and most other plants with a few exceptions. Rats receiving mushrooms as a sole source of protein in their diet, not only survived the six-week test period but made a gain in weight equivalent to 30 percent of that attained by rats on a casein positive control diet (Anderson and Fellers, 1942). When 20 percent of the casein was replaced by mushroom protein, a growth gain was made equal to 84 percent of that of the positive control group. Therefore, although the application "vegetable beefsteak" to the mushroom is hardly appropriate, the protein present in mushrooms is able to support life and promote growth, although not so efficiently as milk protein.

History of Mushroom Culture

Edible fleshy fungi for centuries have served mankind as food, and a considerable folklore, profuse in mystery and superstition, has been built up around them. The Greeks and Romans consumed many species of edible fungi but apparently had no means of mushroom cultivation.

Europeans always have been considerably more enthusiastic about eating wild mushrooms than we in North America. This may be due to the fact that food always has been more scarce in Europe and the population has made use of this natural source. In North America, with the exception of the cultivated *Agaricus campestris*, probably less than one person in a thousand recognizes any species of mushroom and thus is unable to distinguish edible from inedible and poisonous species. In Europe many dwellers in rural areas distinguish varieties of mushrooms as readily as they distinguish different wild flowers. In Continental countries wild mushrooms are gathered and sold as individually recognized varieties, but in most cases only those varieties authorized and inspected may be offered to the public. Wild mushrooms are an important source of food in many areas.

Most fungi used as food are mushrooms, but several other fleshy fungi are of considerable importance. The truffle, a subterranean fungus, which is gathered commercially in southern Europe, is regarded as a gourmet's dish of unparalleled flavor. In France and Italy it was a delicacy in the royal courts as early as the 14th century. The truffle is so prized and commands such a high price that a large percentage of all those collected are sold for the connoisseur's table, and many are canned and exported. They grow only in association with the roots of forest trees, particularly oaks, and being subterranean, can-

TABLE IV

VITAMIN D CONTENT OF VARIOUS MUSHROOMS

Mushroom	International units per gram
Boletus edulis	0.83
Cantharellus cibarius	...
Helvella esculenta	1.25
Agaricus campestris	
Grown in dark	0.21
Open meadow	0.63

TABLE V

LYSINE AND TRYPTOPHANE CONTENTS OF CERTAIN PROTEINS

	Grams obtained from 100 g. of protein	
	Lysine	Tryptophane
Ox muscle	10.00	1.30
Egg	7.88	1.71
Milk	7.10	1.12
Yeast (dried brewer's)	7.28	0.94
Corn (whole)	2.30	0.48
Wheat	2.50	0.83
Soybean (whole)	7.16	1.12

not be found easily without the aid of a keen nosed animal, ordinarily a dog or a female hog, trained for the purpose. The term "truffle hound" is not fanciful, but represents an actuality.

About three quarters of a million pounds of truffles are gathered annually, and the supply is far below the demand.

Many attempts have been made to cultivate the truffle artificially, but thus far without success. It has been possible to inoculate new oak plantations and thus increase the area in which the fungus may be collected, but truffles have never been produced in other than a natural habitat.

The earliest records available indicate that what was then the art of mushroom growing originated in France during the seventeenth century. At that time much of the cultivation was carried out in caves, but later mushrooms were grown in almost every conceivable place, including cellars, sheds, greenhouses, and even in the open. Pure cultures of mycelium or "spawn" were unknown, and it is likely that diseases and insect depredation were much more serious than they are today. There was little evidence of commercial mushroom growing in the United States until about 1880, when an infant industry was established in and around New York City and the Philadelphia area.

Mushroom growing is no longer a small industry but is estimated to be worth around 43 million dollars, exclusive of enterprises depending on mushroom growing, such as trucking, mushroom canning and supply dealing. The industry centers around the Kennett Square area in Pennsylvania, which State produces about 37,000,000 pounds of mushrooms per year of the United States' total of about 62,000,000 pounds. New York, the next largest producer, grows only about 8,400,000 pounds.

Approximately 75 percent of the total production is now canned, including that used for mushroom soup.

The Future Status of Fleshy Fungi as Food

Certain wild species of fleshy fungi have delighted the palates of gourmets for centuries. In addition to the truffle, already mentioned, and, of course, *Agaricus campestris*, other fungi are highly regarded. In particular, the morel (*Morchella esculenta*), is prized for its flavor; the giant puffball (*Calvatia gigantea*) for its size and substance; and the chanterelle (*Canthanellus cibarius*) for its aroma and flavor. The various larger species of inky caps (*Coprinus*), the edible boletus (*Boletus edulis*) and many others are valued for their general edibility. The question naturally arises —why are these species not grown commercially?

With the exception of the cultivated mushroom (*Agaricus campestris*), little success has been obtained in growing fleshy fungi on a commercial scale, although the paddy-straw mushroom (*Volvaria volvacea*) is grown to some extent on ricks of rice straw in the Orient, and the Japanese and Chinese for years have been cultivating a tree-inhabiting mushroom (*Cortinellus berkeleyanus*) on logs cut and inoculated with the fungus. The answer lies in the undetermined nutritional requirements of the different species, especially with regard to their reproductive requirements. Many of the edible fungi have strict symbiotic relationships with the roots of particular species of trees and will not grow elsewhere. In many cases it is relatively easy to obtain mycelial growth on nutritive media, but it has been very difficult to obtain fruiting bodies. If only mycelium were desired, as in submerged culture, the task might be somewhat easier.

A few wild species have been grown by experimenters on a very small scale with sufficient success to suggest that at some time they may be grown in considerable amounts. Dr. Edmund B.

Lambert of the United States Department of Agriculture has been engaged in this problem for many years. He obtained the remarkable yield of seven and two-thirds pounds per square foot of *Coprinus comatus* on wheat bran. Brock (1953) cultivated the prized morel (*Morchella esculenta*) on synthetic media and accumulated a considerable amount of information on its nutritive requirements, but did not obtain fructifications.

To grow fungi commercially as a major source of food, it becomes necessary to obtain a cheap source of nutrient substrate on which the organism will grow. The cultivated *Agaricus*, which yet must be considered a luxury food in terms of price per pound of edible matter, has in the past been grown chiefly on composted horse manure. This was at one time plentiful and could be obtained practically for the haulage charge. Now, with fewer horses, it is relatively unobtainable in many locations, and synthetic composts have been developed to augment or even replace the natural product. However, synthetic compost is relatively expensive and would be impractical to use were not the mushrooms priced to compensate. Cultivated mushrooms are not a cheap source of food, even though they are grown on manure or on waste straw, fodder and chemicals.

With the difficulty in growing some of the edible fleshy fungi, it does not seem possible that under present circumstances any of these forms grown only for their caps or fruiting bodies will ever form an important source of food in this country.

Production of Fungal Mycelium as Food

In contrast to the growth of fungi for their fructifications, the commercial utilization of fungus mycelium for food appears to be quite promising. This is a result in large measure of the development of submerged culture or fermentation techniques. Fungus spores and mycelium, including those of yeasts, have at times been consumed involuntarily in various foods and drinks, sometimes with serious consequence, as in the case of ergot in rye flour. However, voluntary use of fungus mycelium for food is quite recent, with a few exceptions such as the consumption of fungus-ripened Roquefort and Camembert cheeses, and the eating of the crisp unripe smut growths on corn * by the Mexicans and Central American Indians.

The efficiency of any process in which fungi are grown for food depends on the proportion of edible material obtained from the substrate, and on the cost of the media. If this is a waste product, the process becomes even more efficient. Brahmer (1942) described a technique for producing *Torulopsis utilis* by fermenting pentose sugars in distillation residues. He states that production of urea for use as a nitrogen-rich stock feed is preferable to the use of yeast for the same purpose. Industrial processes have tried utilizing fungi other than yeast. Waste sulfite liquor has been fermented by *Oidium lactis*, a mold. The dried powder obtained from this fermentation served as a protein supplement in the manufacture of sausages in Germany, but, because of lack of certain nutritional qualities, use of this mold was discontinued.

In developing the utilization of fungus mycelium as food, a natural tendency is to consider first the mycelium of fungi such as mushrooms which have edible fruiting bodies. *Agaricus campestris*, because of its unique and desirable flavor, was one of the first to be tried. Experiments have shown that it is possible with submerged propagation

* An insoluble crystalline product, ustilagic acid, is formed when certain strains of corn smut are fermented in submerged culture. Originally investigated because of its possible antibiotic value, ustilagic acid has been found to be the precursor of synthetic musk and other potentially valuable products (Roxburg et al., 1954).

or by other means in media containing the proper constituents in the proper concentrations, to produce *Agaricus campestris* mycelium with mushroom-like flavor (Block et al., 1953a, b; Humfield, 1952; Humfield et al., 1948; Humfield and Sugihara, 1949, 1952; Szuecs, 1953; Treschow, 1944).

The mycelial product tastes much the same as the commercial fruiting body, provided growth is prolonged two days beyond the point of total sugar utilization. If the process is stopped at the time of total sugar utilization, the product is essentially the same nutritionally but is flavorless. The yield on a wet basis is 100 g of mycelium per liter of five-percent sugar solution (Humfield and Sugihara, 1948). Analysis of the product is given in Table VI. On a dry basis, 40 to 50 g. of mycelium may be obtained per 100 g. of sugar. Humfield and Sugihara (1952) found that not all strains of *Agaricus campestris* are adapted to submerged culture. Many fail to grow, or grow but slowly.

TABLE VI

ANALYSIS OF *Agaricus campestris*

	Commercial fruiting body	Fermentation-produced mycelium	
		White variety	Cream variety
Protein (N × 6.25)	37.25	35.5	45.3
Fat (ether extract)	1.81	2.3	...
Carbohydrate	38.19	48.8	...
Fiber	10.38	6.92	...
Ca	0.023	0.12	0.106
P	1.42	1.28	1.24
Fe	0.019	Trace	Trace
Ash	12.00	4.59	5.24

Since little work has been done on the production of mushrooms other than *Agaricus campestris* in fermentation, many think it would be profitable to explore this field further, especially with species mentioned previously as being desirably flavored. This would be most interesting research and in some cases the results might prove very profitable.

In view, however, of the previously mentioned nutritional difficulties with the forest species of fleshy fungi, their use for fermentation studies does not seem so practical as that of the molds and yeasts.

A personal conversation with Professor Lembke, M.D., was recorded by interviewers (Botticher et al., 1942) investigating German industry following World War II, in which he stated that he had used several strains of molds in human feeding. Food preparations were made by him from strains of *Fusarium Candida, Oidium, Endomyces* and *Rhizopus*. Lembke stated that the general health of the people to whom these molds were fed was better than that of the people acting as controls. He suggested that his strain of *Fusarium* was probably the most satisfactory. The East Munich Dairy Station was reported by him to be growing *Fusarium* on whey. In unrelated Canadian studies (Graham et al., 1953) the food value of whey was increased considerably by yeast fermentation. The strains of *Fusarium* and *Rhizopus* used by Lempke were high in cystine, methionine and glutathione. As most yeasts are low in the amino acid, cystine, it appears that molds would be more satisfactory fungi to use for human food production, provided they are equal to food yeast in other essential respects. Use of molds for this purpose has received only slight consideration, and to our knowledge, no industrial mycological research has been conducted to investigate this source of food supply. The present knowledge of the protein constituents of mold mycelia is fragmentary and incomplete.

Aspergillus oryzae has been studied by Takata (1929) from the standpoint of its utilization as food for persons. The following amino acids were reported to be synthesized by this mold: arginine,

histidine, lysine, cystine, tyrosine, and tryptophane. Takata found, however, that, although *Aspergillus oryzae* mycelium contained 38 percent protein (80 percent digestible) and permitted good growth of albino rats, it was deficient as a sole protein source. He did find that it was high in vitamin B.

Yeasts may be classified non-technically into baker's, brewer's, and cultured. Baker's yeasts are used mainly in the production of carbon dioxide for raising dough. For some years these yeasts were consumed in large quantities as sources of the vitamin-B complex, in addition to baking, but now are not recommended as a human food source by the U. S. Food and Drug administration because the thiamine and riboflavin of such yeasts are very poorly utilized (Sure, 1950).

Brewer's yeast is a by-product of the brewing industry. In each barrel of beer after aging there is deposited about one-half pound of bottom yeast. It is primarily used in animal feeds, since the yeast is too bitter for human consumption in the untreated form, but some is debittered with a mild alkali and sold as "dried brewer's yeast".

Cultured yeasts are produced in stainless steel vats, using any strain of yeast desired, a sugar for energy, and an ammonium salt to supply nitrogen. Cultured yeasts are considerably more palatable than brewer's yeast, have been produced commercially, and undoubtedly will become more important in the future.

Protein Production. A difficulty in animal experiments using fungus protein results from the fact that, to cover the protein requirements of the animals, the mold mycelium must make up 50 percent of the total food consumed. This means that a large quantity of undesirable material must be ingested. When surface-formed mats of *Penicillium notatum* are fed to rats, a severe diarrhea results. It was reported by Lembke, in records of the human feeding experiments performed by him, that these materials caused diarrhea if they were not completely autolyzed by heating. Wooley and associates (1938) reported that mycelium of *Aspergillus oryzae* was toxic to rats, but the toxicity could be overcome by addition of other protein complexes to the diet. Mycelia from *A. fischeri, A. oryzae, P. chrysogenum* and *A. sydowi* were toxic to rats when they composed 50 percent of the food consumed. This toxicity was overcome by supplementing the diet with casein or yeast. This may have been an instance of folic acid deficiency, which apparently has not been investigated.

A similar instance of the need for supplements to mold protein was reported by Skinner and associates (1940) who worked with *Penicillium flavo-glaucum, P. roquefortii* and *Geotrichium lactis*. They concluded that these molds were inadequate because of the low cystine content of the protein.

Vinson and associates (1945) found that *Fusarium lini* mycelium supplemented with thiamine was a satisfactory source of protein and vitamins for normal growth, reproduction and lactation in mice. They also found that *Fusarium graminearum* was satisfactory only if supplemented with multiple B vitamins.

Clutterbuck (1932) isolated a protein fraction from *Penicillium notatum* and *P. chrysogenum*, which, upon hydrolysis with enzymes and acids, was found to contain melanin, arginine, histidine, cystine and lysine.

Gorcica and associates (1935) found that incorporation of ten percent *Aspergillus sydowi* mycelia in a food ration low in vitamin B complex supported good growth in rats. Enough vitamin B_1 was present in food containing ten percent *Aspergillus sydowi* mycelia to protect chicks against polyneuritis. One percent of mold mycelia counteracted

pellagra in chicks containing little vitamin B_2 (vitamin G). Mold fed at a level of 30 percent prevented paralysis of chicks on a diet low in vitamin B_4. Three percent *Aspergillus sydowi* was necessary for good growth in chicks.

Nikisch (1951) found *Oidium lactis* and yeast to be a good protein source for dogs in a ten-week study in which 30 grams of dried material were given per day. The yields and protein content of yeasts grown in different media are shown in Table VII.

Fat Production. In countries where fat requirements may be met by domestic production from animals and higher plants, or by importations, one would not ordinarily attempt to produce fats from microorganisms commercially. In times of emergency, however, when the usual supply becomes inadequate, it could be profitable to synthesize fat from waste carbohydrate materials by means of microorganisms.

Fat may be produced by a number of different microorganisms: by yeasts; by yeast-like molds, such as *Oospora* (*Oidium*) *lactis;* and by filamentous molds. Fat production is a normal function of yeast cells, but the rate of its formation and the quantity stored may be increased by means of certain optimum conditions. Lindner (1944) and others developed several processes for obtaining fat from the yeast *Endomyces vernalis.*

The production of fat from the yeast *Rhodotorula gracilis* has been described by Enebo and associates (1946). Fat contents of 50 to 60 percent (on a dry basis) were obtained in a non-continuous cultivation with about 51 liters of substrate. The fat coefficient (grams of fat produced/grams of carbohydrate utilized) was 16 to 18; the generation time, 15 to 20 hours, and the protein content, 12 to 13 percent.

Oidium lactis, a yeast-like mold, usually found in Camembert cheese along with *Penicillium camembertii,* produces quantities of fat. Fink and his coworkers (1937) developed a method of fermenting milk whey with this organism. In the process, the fat content of the dry mycelium was approximately 22 percent, with a fat coefficient of 12–14/100. With regard to the fat coefficient, it is interesting to note that Rippel (1940) calculated the maximum yield of fat to be expected from any organism. This calculation was made on the basis of energy relations. He predicted that no more than 15 grams of fat could be obtained from 100 grams of carbohydrate substrate. This value has been approached but has not been exceeded to date.

TABLE VII

YIELDS AND PROTEIN CONTENTS OF YEASTS GROWN IN DIFFERENT MEDIA

Yeast	Medium	Dry yeast yield, percent	Protein content, percent
Torulopsis utilis No. 3	Wood hydrolyzates	30.5–52.6	51.9–58.6
"	Sulfite liquor	29.6–39.2	51.0–52.7
"	Fermentation residue	47.0–52.0	50.0
"	Wood sugar stillage	53.0–63.0	52.9
"	Molasses	56.0	Av. over 50.0
"	Fruit juice	53.0	"
Candida arborea	Molasses	55.0–64.0	38.8–49.4
Hansenula anomala	Wood hydrolyzates	35.0–40.0	....
Hansenula suaveolens y-838	Wood sugar stillage	53.0–63.0	53.4
Mycotorula lipolytica P-13	Wood hydrolyzates	35.0–40.0	....
"	Wood sugar stillage	53.0–63.0	51.0
Oidium lactis	Molasses	55.8–60.0	31.2–41.9
Saccharomyces cerevisiae	Molasses	42.7–54.3	42.5–53.1

As early as 1906 (Browne) it was found that the dried mycelium of a form of *Penicillium* that had grown on the surface of tanks of leftover molasses contained as much as 27.5 percent of fat which in a number of ways resembled butterfat. Since that time a number of other species of molds have been found to produce fat, but the study of the fat produced by filamentous fungi has been limited almost entirely to species of *Penicillium*, *Aspergillus* and *Fusarium* (Pruess et al., 1934). A considerable variation in fat production occurs not only between species but also between different strains of the same species.

TABLE VIII

SOME MOLDS CONTAINING MORE THAN 15 PERCENT OF CRUDE FAT

Mold	Crude fat in dried mycelium, percent
Penicillium bialowiezense ...	17.0
Penicillium citrinum	18.1
Penicillium hirsutum	16.4
Penicillium soppi	20.2
Penicillium javanicum	22.2
Penicillium roqueforti	22.9
Penicillium oralicum	24.4
Penicillium pisicarum	26–28
Penicillium flavocinerium ...	28.5
Aspergillus flavus	16.0

Cultural conditions are likewise important: the concentration of the sugar, the kind and quantity of nitrogen-containing substance, the presence of small quantities of materials that stimulate fat production, the pH, the temperature, and the incubation period. Of 39 species of *Penicillium* and 22 of *Aspergillus*, ten contained more than 15 percent of crude fat, but only six had more than 20 percent, as indicated in Table VIII (Prescott and Dunn, 1949).

During World War II, a successful submerged-vat process of growing molds was developed by Damm (1944), which gave results superior to that achieved by the shallow-pan method of Lindner's process. The best results were obtained with a selected strain of *Fusarium* which reaches maximum growth and fat content in 40–48 hours. A great variety of substrates can be used as carbon sources by this organism: glucose, fructose, organic acids, acid amides, disaccharides, and pentoses (utilized more slowly). Oil of *Fusarium* is quite similar in analysis to peanut oil and olive oil and is said to be interchangeable with these for human consumption and in industry. Fatty acids of *Fusarium lini* were investigated by Fiore (1948). The following analysis is given: palmitic, 19.8 percent; linoleic, 32.9 percent; and oleic, 37.3 percent. Among the new fatty acids discovered in fungi are spiculosporic acid from *Penicillium spiculosporium* (Clutterbuck et al., 1931) and ninioluteic acid from *Penicillium ninioluteum* (Birkenshaw et al., 1934).

Several reviews or surveys of fat production by fungi have been written recently (Merino, 1951; Murray et al., 1953; Woodbine et al., 1951).

Production of Organic Acids and Other Products Used in the Food Industry. Many fungi produce, or are used in the production of, accessory edible materials which cannot be considered foods in the strictest sense but are utilized in the food industry, for example: wines, beer, extracts, flavorings, and certain organic acids. Some enzymes produced by fungi fall in this category, but will be considered separately. In fermentative processes of benefit to the food industry, the organisms concerned may be bacteria, yeasts or molds. Although bacteria are used in the ripening of certain cheeses, in the production of vinegar and sauerkraut, and in other processes, this group of organisms will not be considered further, since they under no circumstances can be considered, per se, as a source of human or animal food. On the other hand, although yeasts and molds also produce

fermentive food products, some, for example, brewer's yeasts, may be used for their intrinsic food value also.

Glycerol is a product of many industrial uses, with minor use as a food and a sweetening agent. It is prepared principally by the saponification of fats and oils, and synthetically from propylene or propane. A very small amount of free glycerol is found in palm oil and in some less common oils. It may also be manufactured by yeast fermentation processes from basic carbohydrates, such as sugar, molasses and hydrolyzed starchy materials.

Many valuable or potentially valuable industrial products are obtained through mold fermentation, and a large number of mold species are concerned. However, from a general industrial standpoint, species of *Aspergillus, Penicillium, Rhizopus* and *Mucor* are by far the most important, particularly *Aspergillus niger*. Strains of this organism are used in at least three important industrial fermentations—those of citric, gluconic and gallic acids. The same acid or other product, however, may be produced by more than one mold.

Production of citric acid by mold fermentation on a commercial basis has been a highly important achievement in industrial microbiology. It has made the United States self-sufficient in respect to the citric acid supply, and has greatly changed the commerce of the world in citric acid and calcium citrate.

Gluconic acid, used principally as a pharmaceutical, may be produced by fermentation by several molds, including *Aspergillus niger*. Calcium is supplied to children and pregnant mothers, principally as calcium gluconate.

Some of the other more important products formed from molds are shown in Table IX.

TABLE IX

A Partial List of Products Formed by Molds

Acids	Alcohols	Enzymes	Polysaccharides	Sterols	Miscellaneous
Acetic	Ethyl	Amidase	Capreolinose	Cholesterol	Aldehyde
Aconitic	Glycerol	Amylase	Galactocarolose	Ergosterol	Ergot
Allantoic	Mannitol	Catalyse	Glycogen	Fungisterol	Ethylacetate
Carlic	....	Cytase	Gums	Phytosterol	Antibiotics
Citric	....	Dextrinase	Luteic acid	....	Lipins
Formic	....	Dipeptase	Mannocarolose	....	Vitamins
Fulvic	....	Enulsin	Mycodextrin	....	....
Fumaric	....	Eripsin	Polygalactose	....	....
Fusarinic	....	Inulase	Polymannase	....	....
Gallic	....	Invertase	Rugulose	....	....
Glaucic	....	Lactase	Selerotiose	....	....
Glauconic	....	....	....	....	....
d-Gluconic	....	....	....	....	....
Glycolic	....	....	....	....	....
Itatonic	....	Lecithinase	Starch	....	....
Itatartaric	....	Lipase	Trehalose	....	....
Kojic	....	Maltase	Varianose	....	....
Lactic	....	Nuclease	....	....	....
Luteic	....	Protease	....	....	....
Malic	....	Raffinase	....	....	....
Malonic	....	Rennet	....	....	....
Oxalic	....	Sulfatase	....	....	....
Penicillic	....	Tannase	....	....	....
Pyruvic	....	Urease	....	....	....
Stipitatic	....	Zymase	....	....	....
Succinic	....	....	....	....	....
Terrestric	....	....	....	....	....

Enzyme Production. The microorganisms of fermentation are notable for their ability to produce enzymes. Molds, yeasts and bacteria can elaborate a wide variety of enzymes, possibly a greater range than any other single cells, since all the functions of growth (reproduction, digestion, etc.) that are distributed among the various tissues and organs of higher plants and animals seem here to be concentrated in the single minute cell. Commercial use is made of some of these enzymes in various industrial processes, including certain ones in the food industry. Four principle enzyme types are most important: amylases (diastases), invertase, proteases, and pectinase.

Amylases are important in many saccharification processes. In such processes, starches, hemicelluloses and celluloses are the basic products but must be saccharified, that is, hydrolyzed or converted to fermentable sugars by enzymatic or chemical agencies before they may be used for most industrial purposes.

Amylases which may be produced from either molds or bacteria are used in the preparation of sizes and adhesives, in the designing of textiles, for the removal of starch from apple pomace in the manufacture of pectin, in the pharmaceutical trade, and for other purposes. In each of these cases the action of amylases is initially upon starch, and after the desired conversion of this substance has taken place, the enzymes are usually destroyed by heat.

Wood-decaying fungi secrete amylases and other enzymes which saccharify the wood. Evaluations of such fungi are being made to determine whether they may be adapted to industrial use. Wood, on which *Pleurotus japonicus* was cultivated for 14 days, could be completely saccharified with 0.3 percent of sulfuric acid under seven atmospheres in seven and one-half minutes (Abe and Fujii, 1950).

Amylases and sometimes other enzymes are used to a limited extent by commercial bakeries to improve the baking value of a flour (Greup, 1953; Reed, 1952; Skouholt, 1952).

Invertase, which may be produced from yeasts or molds, converts sucrose to glucose and fructose by inversion, thus making possible sugar content without crystallization. Invertase is used by bakers, sirup manufacturers and confectioners.

Proteases, which may be obtained from *Aspergillus flavus* or from bacteria, are employed also for several purposes. They may be used in the degumming of silk goods, in the dehairing and bating of hides, in the manufacture of liquid glue, as a substitute for or combined with soap in the laundry business, and as an agent in the ripening of cheese. The term "proteases", as used, refers to a mixture of proteolytic enzymes which may include true proteinases and peptidases.

Pectinase, usually obtained from species of *Penicillium*, may serve to aid in the clarification of fruit juices. Enzymes that hydrolyze pectin are also important in retting processes, as in the manufacture of linen from flax.

Acceptance of Fungal Food

In the past, the cause of many famines has been in food distribution, not in actual lack of food. There never has been a time when famine was world-wide, but, on the other hand, there never has been a time when political and sociological circumstances made world-wide distribution of food possible.

Whether the time will come when the world as a whole will be unable to produce enough food to feed its population has been a debatable question for years, but we can make better use of our present food supply, take advantage of new food sources now available, and delay or prevent what some claim to be an eventu-

fermentive food products, some, for example, brewer's yeasts, may be used for their intrinsic food value also.

Glycerol is a product of many industrial uses, with minor use as a food and a sweetening agent. It is prepared principally by the saponification of fats and oils, and synthetically from propylene or propane. A very small amount of free glycerol is found in palm oil and in some less common oils. It may also be manufactured by yeast fermentation processes from basic carbohydrates, such as sugar, molasses and hydrolyzed starchy materials.

Many valuable or potentially valuable industrial products are obtained through mold fermentation, and a large number of mold species are concerned. However, from a general industrial standpoint, species of *Aspergillus, Penicillium, Rhizopus* and *Mucor* are by far the most important, particularly *Aspergillus niger*. Strains of this organism are used in at least three important industrial fermentations—those of citric, gluconic and gallic acids. The same acid or other product, however, may be produced by more than one mold.

Production of citric acid by mold fermentation on a commercial basis has been a highly important achievement in industrial microbiology. It has made the United States self-sufficient in respect to the citric acid supply, and has greatly changed the commerce of the world in citric acid and calcium citrate.

Gluconic acid, used principally as a pharmaceutical, may be produced by fermentation by several molds, including *Aspergillus niger*. Calcium is supplied to children and pregnant mothers, principally as calcium gluconate.

Some of the other more important products formed from molds are shown in Table IX.

TABLE IX

A Partial List of Products Formed by Molds

Acids	Alcohols	Enzymes	Polysaccharides	Sterols	Miscellaneous
Acetic	Ethyl	Amidase	Capreolinose	Cholesterol	Aldehyde
Aconitic	Glycerol	Amylase	Galactocarolose	Ergosterol	Ergot
Allantoic	Mannitol	Catalyse	Glycogen	Fungisterol	Ethylacetate
Carlic	....	Cytase	Gums	Phytosterol	Antibiotics
Citric	....	Dextrinase	Luteic acid	....	Lipins
Formic	....	Dipeptase	Mannocarolose	....	Vitamins
Fulvic	....	Enulsin	Mycodextrin	....	....
Fumaric	....	Eripsin	Polygalactose	....	....
Fusarinic	....	Inulase	Polymannase	....	....
Gallic	....	Invertase	Rugulose	....	....
Glaucic	....	Lactase	Selerotiose	....	....
Glauconic	....	....	....	....	....
d-Gluconic	....	....	....	....	....
Glycolic	....	....	....	....	....
Itatonic	....	Lecithinase	Starch	....	....
Itatartaric	....	Lipase	Trehalose	....	....
Kojic	....	Maltase	Varianose	....	....
Lactic	....	Nuclease	....	....	....
Luteic	....	Protease	....	....	....
Malic	....	Raffinase	....	....	....
Malonic	....	Rennet	....	....	....
Oxalic	....	Sulfatase	....	....	....
Penicillic	....	Tannase	....	....	....
Pyruvic	....	Urease	....	....	....
Stipitatic	....	Zymase	....	....	....
Succinic	....	....	....	....	....
Terrestric	....	....	....	....	....

Enzyme Production. The microorganisms of fermentation are notable for their ability to produce enzymes. Molds, yeasts and bacteria can elaborate a wide variety of enzymes, possibly a greater range than any other single cells, since all the functions of growth (reproduction, digestion, etc.) that are distributed among the various tissues and organs of higher plants and animals seem here to be concentrated in the single minute cell. Commercial use is made of some of these enzymes in various industrial processes, including certain ones in the food industry. Four principle enzyme types are most important: amylases (diastases), invertase, proteases, and pectinase.

Amylases are important in many saccharification processes. In such processes, starches, hemicelluloses and celluloses are the basic products but must be saccharified, that is, hydrolyzed or converted to fermentable sugars by enzymatic or chemical agencies before they may be used for most industrial purposes.

Amylases which may be produced from either molds or bacteria are used in the preparation of sizes and adhesives, in the designing of textiles, for the removal of starch from apple pomace in the manufacture of pectin, in the pharmaceutical trade, and for other purposes. In each of these cases the action of amylases is initially upon starch, and after the desired conversion of this substance has taken place, the enzymes are usually destroyed by heat.

Wood-decaying fungi secrete amylases and other enzymes which saccharify the wood. Evaluations of such fungi are being made to determine whether they may be adapted to industrial use. Wood, on which *Pleurotus japonicus* was cultivated for 14 days, could be completely saccharified with 0.3 percent of sulfuric acid under seven atmospheres in seven and one-half minutes (Abe and Fujii, 1950).

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ality. So long as we are animals and human beings at the same time, the two most logical solutions to the problem, birth control and cannibalism, will never be considered.

The greatest need for added protein or fat, or for food generally, is in the overpopulated lands of the Orient where the diet is limited to certain foodstuffs by religion or compelling tradition. Efforts to improve the diets of such peoples by the introduction of novel foods have met with great resistance from these needy populations. Almost invariably they refuse to eat other foods or change their food habits; for example, they refuse to eat unpolished rice, and so suffer from beriberi, even though it has been proved that the lack of thiamine in a diet of polished rice causes beriberi. In sections of the Philippines, the people are protected against themselves by fortifying the rice with vitamins at the mills.

There is no religious taboo against eating fungi. So, if a natural prejudice toward new and unusual food materials can be overcome, there seems to be no reason why the use of fungi for food should not increase rapidly. We must recognize, of course, that there are certain factors, other than technical feasibility and dietary acceptance, which must be considered. Even though it were found practical to supplement the diet with fungus food, this could substitute for only a fraction of conventional proteins and fats. Compared on the same basis, mushrooms contain about one-tenth as much protein as meat or fish and about a hundredth as much fat as pork. Obviously we cannot replace conventional proteins and fats with fungus food completely. The large bulk required would be out of the question, and such large amounts of fungus, even if not toxic, would lead to a very unbalanced diet. In actual practice with food yeast, the amounts consumed are of the order of a few grams per person per day, and the same will be true with other types of fungi as well.

Economics of Commercial Food Use of Fungi

If fungus food were necessary and acceptable, we would still have to consider the economics of the situation. It has been estimated that, with a $1,100,000 plant, costing $930,000 per year to operate, 6,000 tons of food yeast could be produced annually at a cost of 7.7 cents per pound. This seems very reasonable, compared with beef and butter, but the comparison should be made with rough fish and cheap oils that are staples among the hungriest of the world's people. By this comparison we might find fungus food in an unfavorable competitive position.

The great potential use of food fungi reposes in the utilization of surplus materials such as wood wastes, vegetable debris, unused factory by-products, sulfite liquors, and even sewage. Such materials not only are wasted at present, but even create a disposal problem. Under these conditions, consideration of actual production costs may be modified by disposal costs.

The possibilities of finding cheap, suitable, low-cost fungus food are still challenging. There is a reasonable possibility that synthetic photosynthesis may become a reality within the next decade or so, dispensing with the need for any other non-conventional method of amending the food supply. Until this occurs, however, many scientists will consider that the fungi offer good possibilities for a rapid method of increasing our food supply.

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The Significance of Micronutrients

Boron, calcium, copper, iron, manganese, molybdenum, sulphur, zinc, sodium and iodine, beneficial to plants though not all known to be essential for normal development, can influence the vitamin, the protein and the carbohydrate content of food plants. Fertilizing practise, based on this understanding, is one of the great fields of applied botany, the practical agricultural aspects of which are surveyed in this article.

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Introduction

The subject of micronutrients, or trace elements, or minor elements, as they are also called, has been extensively investigated (6). Their importance is universal, and in most countries of the world, micronutritional problems exists. Nevertheless, deficiencies of micronutrients are still looked upon as unusual, and rather localised, occurrences. Their important role in nature is frequently ignored, and they are not investigated unless acute deficiencies cause agricultural difficulties.

This is an unfortunate state of affairs because, while it may be true that the bulk of research on micronutrients is of an empirical agricultural nature, the biochemical, physiological and ecological importance of these substances has been partly investigated. While the more fundamental type of information is not extensive, enough is available to enable the role of the nutrients to be assessed. This paper discusses some of them.

Definition

At the very outset problems of terminology arise. The terms " minor element ", " trace element ", " micro elements " are not entirely synonymous and are not really adequate. As is well known, there are a number of *essential elements* without which plants do not grow and which are required for proper development. If they are entirely absent, plants cannot grow, while if they are not present in adequate quantities, deficiency diseases may occur. As nitrogen, phosphorous and potassium are elements which have been traditionally supplied to soils in fertilizers and occur in large quantities in plants, they were rapidly named the " major elements ". These are the macronutrients whose role in nature is generally appreciated. More recently, some workers have included magnesium, calcium, sulphur and iron in this group.

Boron, copper, manganese, molybdenum and zinc are termed " micronutrients ", while for animals cobalt and iodine are definitely in this group as well, although their role in plants is certainly not clear.

The term " trace element " is not useful, since the concentration of these elements varies from variety to variety of plants, and some species even accumulate large quantities of " trace elements ". Again not all " trace elements " can be shown to be essential for normal development. The same is true for the term " minor element ". It seems more logical to use the more modern terminology and call all elements necessary for plant and animal development

" nutrients ". Nitrogen, phosphorous, potassium and magnesium are best termed " macronutrients " and the other essential elements " micronutrients ". The distinction between the two groups is arbitrary, as any distinction based on concentration must be. The same is true in assessing the essential nature of certain elements, such as sodium, which definitely have a very stimulating influence on plant growth but have not clearly been shown to be absolutely necessary for development.

Yields

While the most obvious result of deficiencies of micronutrients is abnormal development, frequently involving various types of chlorosis which can readily be identified (9, 41), by far the most important result is a marked decrease in crop yield or quality, sometimes in both.

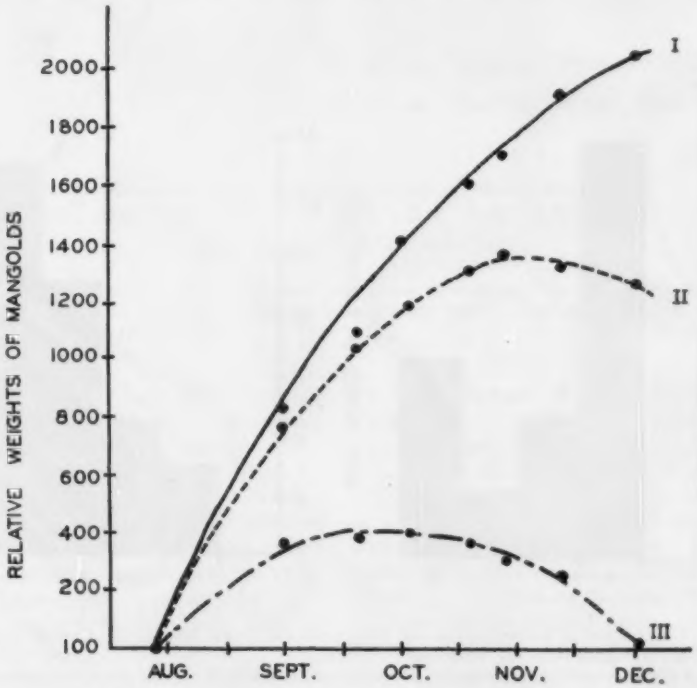

FIG. 1. Mangolds, germinated on a full nutrient solution, transplanted into water culture pots on the 13th August, harvested on the 16th December of the same year.

I. Nutrient solution containing 1 mg. H_3BO_3 per litre for this entire period.

II. Nutrient solution without boron from the 2nd October to the 16th December.

III. Nutrient solution lacking boron for the entire experiment.

Note the great differences in yields (wet weight).

In I no deficiency symptoms developed. In II general deficiency symptoms did not set in until the 4th–13th November. At this stage the plants started to lose weight. In III deficiency symptoms set in at the beginning of October.

Crop production is seriously retarded by lack of boron before visual deficiency symptoms set in. (*After E. Brandenburg*)

Fig. 1 shows the obvious limiting effect of boron deficiency on crop yield in mangolds (4) under strict laboratory conditions. That similar striking results can be obtained in the field is clearly shown in Fig. 2, where the limiting action of deficiencies is revealed (14). In both these cases the macronutrients could be efficiently used only when adequate supplies of the deficient micronutrient were made available.

It is important to grasp the fact that micronutrients are not substitutes for macronutrients. They are important because they enable the plant to utilise the macronutrients efficiently and economically. Occasionally a soil may have accumulated large quantities of N, P or K, and it may not be necessary to supply these for a few years, while it still remains necessary to furnish micronutrients at least annually. But when the reserves have been exhausted, the macronutrients must again be supplied, or else they will become the limiting factors in crop production. It is because micro-

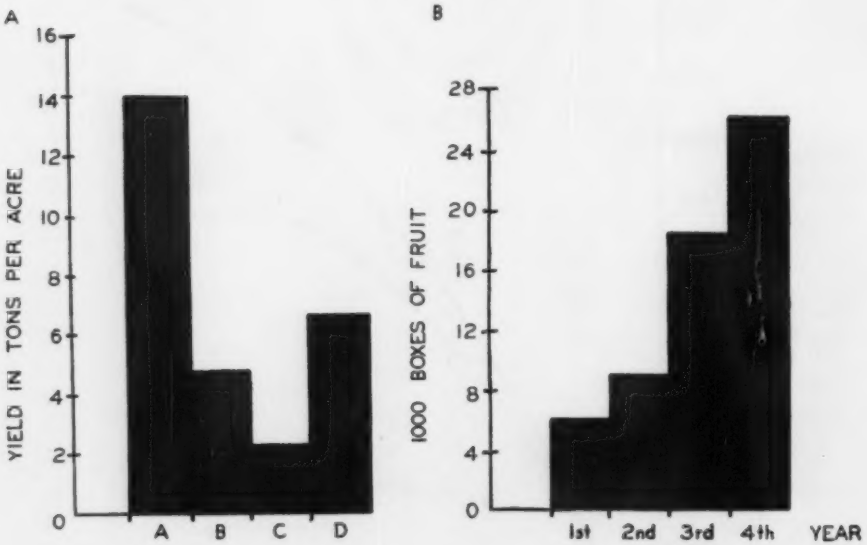

Fig. 2. Influence of micronutrients on crop yield. A. Sugar beet in Co. Carlow, Eire, grown under field conditions with the following treatments:

A: Farmyard manure + artificial fertilizers + lime + 20 lb. Borax per acre–14 tons 12 cwt. per acre.

B: Farmyard manure + artificial fertilizers + lime–4 tons 12 cwt. per acre.

C: Farmyard manure–2 tons 8 cwt. per acre.

D: Farmyard manure + artificial fertilizers–6 tons 15 cwt. per acre. (*After J. Joyce*)

B. Field results obtained on a run-down fruit farm in the Cape Province, South Africa. Adequate macronutrient fertilizers were available. Sprays of zinc and manganese compounds caused marked increases in the yield of apples and pears. Note that it may take more than one season for full beneficial results of the sprays to be obtained.

1st year—no spray — 6,000 boxes of fruit.
2nd year—Mn & Zn spray— 9,000 boxes of fruit.
3rd year— " " " " —18,000 boxes of fruit.
4th year— " " " " —26,000 boxes of fruit.

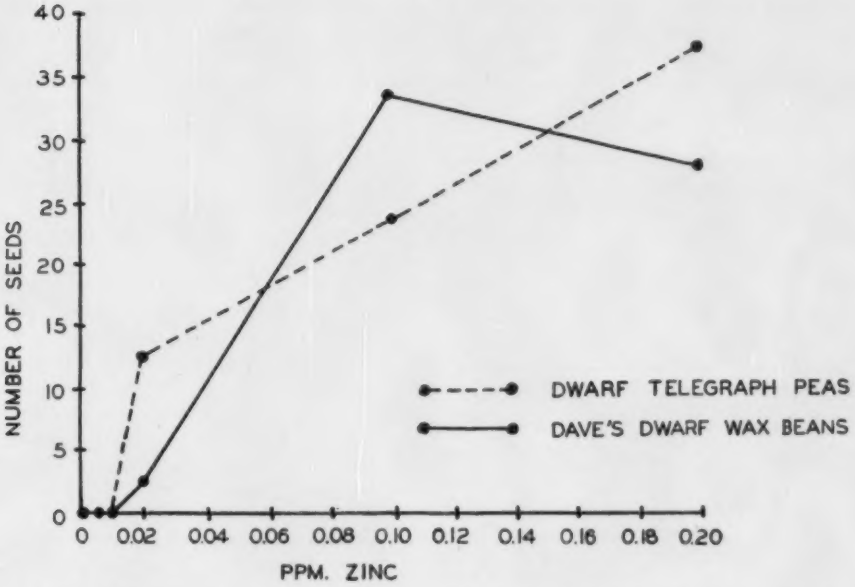

FIG. 3. The influence of zinc on the seed production of peas and beans. At very low concentrations of zinc, no seeds are produced, while at slightly higher concentrations, seed production is proportional to the zinc content. (*After H. S. Reed*)

nutrients frequently are the unrecognized limiting factor in crop production that such spectacular increases in yield can be obtained by application of micronutrient fertilizers.

Micronutrition may be very complex. As Reed (27) showed, plants may contain adequate amounts of zinc for vegetative development and appear quite healthy, yet not have enough zinc for seed production. The threshold value for seed formation is much higher than that for vegetative growth (Fig. 3). It is thus necessary to bear in mind that soil fertilization for seed production may be different from that for vegetative tissue.

Another example of this complexity is given by Scharrer (31), working on copper-deficient German soils. He found that applications of copper to wheat crops increased the yield appreciably, but that this was mainly an increase in the weight of straw, while ear production was not raised. However, the crude protein content of his plants was increased.

By altering the micronutrient balance of a crop it is possible to influence different organs in various ways. With a better knowledge of plant physiology, it should be possible to fertilise crops to achieve definite desired results, such as the maximum production of crude protein for fodder purposes. This type of fertilization is already possible with macronutrients, to a limited extent.

While in general, deficiencies of micronutrients decrease the total yields, this is not always the case. Roach (28) reports that the largest crop of mangolds that he ever saw, namely, 70 tons per acre, was very severely deficient in manganese throughout its entire development. It is quite possible that certain deficiencies

may promote root formation at the expense of the rest of the plant. If this is true, slight deficiencies in certain crops may be very desirable.

Enzymes

The rather spectacular role played by micronutrients as opposed to macronutrients is due to their different function in the well-being of the organism. Micronutrients are mainly associated with enzyme systems, and some of them, such as copper in the enzyme tyrosinase, are definitely known to be part of enzyme complexes. Table I shows some of the relationships that are known to exist.

TABLE I

RELATIONSHIPS BETWEEN ELEMENTS AND ENZYME SYSTEMS

Element	Enzyme system of which it is a part, or with which it is associated
Copper	Tyrosinase (potato)
	Ascorbic acid oxidase (cabbage)
	Indophenol oxidase
	Polyphenoloxidase (potato, mushroom, tea)
Cobalt (animal)	Peptidases
	Dipeptidases
	Catalase
	Desoxyribose nuclease
Manganese	Catalase
	Oxidases
	d-Arginase
Molybdenum	Nitrate reductase
Zinc	Carbonic acid anhydrase

From the practical point of view, it is important to remember that all chemical processes of plants are controlled by enzyme systems and that only a proper co-ordination between these processes results in normal healthy development. Sub-minimal concentrations of essential enzyme systems will seriously hamper normal growth and act as limiting factors in development. Inadequate supplies of certain elements can bring this about. As a result, the organism will have to re-adapt its metabolism and adjust itself to new circumstances, which may result in deficiency diseases. If the deficiency is acute enough, the plant cannot adapt itself and death must result.

Not all plants have identical enzyme systems, and so it is possible to find species and varieties with lower nutrient requirements than those of most plants. These are the so called resistant varieties, i.e., varieties that do not show certain deficiency diseases (25). The same holds true for toxic concentrations of micronutrients. Concentrations which are harmful to some varieties are harmless to others (16). Certain types of beans are very sensitive to high concentrations of manganese, while *Vaccinium* tolerates very high concentrations without harm. Plants definitely have different nutritional requirements, and in nature this appears to be an important ecological factor governing distribution.

Enzyme systems associated with micronutrients also appear to govern the concentration of certain vitamins, the amino acid constitution of proteins and many other phenomena of great interest. Some of these are discussed below.

Soil Fertility

Micronutrients, being essential nutrients, are intimately linked with the problem of soil fertility. But exactly in what way is rather difficult to discuss, as the concept of soil fertility is so vague. Some workers use the term in such a manner that it is completely divorced from any connection with vegetation. Chemical analysis of the major elements is taken as a criterion of soil fertility. In a limited area, with a good background of practical empirical experience, these methods may be a reliable guide to the nutritional status of a soil. But in territories which have only recently been developed, especially in the tropics, this is not the case and soil analysis may be misleading.

A fertile soil must surely be one that bears good crops. Fertility must be expressed in terms of vegetation produced. But as plants have such different nutritional requirements, it is obvious that soils fertile for one type of vegetation may be useless for another. To cite some examples. In work done by Löhnis (16), plots containing high levels of manganese were definitely not fertile for *Phaseolus vulgaris* but reasonably fertile for *Trifolium repens*. In the copper-deficient North German Plain, buckwheat grows well but oats show serious deficiencies (25). Many tropical rain forest soils, when cleared for agriculture, are very rapidly leached and are infertile for crops. Yet under natural conditions they support luxuriant growth.

The fertility of a soil is not easily measured by any ordinary chemical analysis, for much of the potential plant nutrient of a soil is present in a form unavailable to the plant and cannot be utilised by it. By altering soil conditions it is often possible to make certain nutrients more available, or vice versa (12). Overliming, for instance, can induce deficiencies of boron, copper, iron, manganese and zinc, while molybdenum is made more available. High phosphate applications may induce zinc deficiency, and high potassium, magnesium deficiency (4). The humus and clay of a soil may very rapidly "fix" certain ions and make them unavailable to plants. This availability of ions is not the same for all plants, and some root systems are able to utilise elements which others cannot, as is clearly shown in Florida where a grass (*Setaria* sp.) accumulates zinc, while maize grown in the same area is zinc-deficient. So the term "plant-available" element may not mean very much unless the type of plant is stated.

Deficiencies can be induced also by heavy applications of ordinary fertilizers. As crop production is increased by fertilizer applications, concentrations of micronutrients which were adequate for low crop yields become inadequate for the increased requirements of the plant; the level of micronutrients becomes the limiting factor in crop production, and deficiencies may ensue. This was already shown in the classic work of Brandenburg (4) as long ago as 1938. Thus it is necessary to remember that areas with high crop yields have a high micronutrient requirement. As crop production is increased, more of these deficiencies must be expected to appear, for modern fertilizers tend to be chemically purer and to supply less micronutrient than old fashioned ones did. Heavy cropping removes larger quantities of micronutrients from the soil, which are not made good by ordinary fertilizer application, while the rate of weathering of many soils is too slow to make good this loss.

Some infertile soils, especially in Australia and Africa, have responded in a most spectacular manner to small applications of micronutrients. Large areas, one useless, have been made available for agriculture at very slight expense. But it must be remembered that these results are abnormal. It is very seldom that only one single factor is so much in the minimum that its increase will turn waste land into fruitful agricultural soil. The majority of field problems are far more complex.

It is found in many parts of the world that soils become less fruitful with use. They become less fruitful, "tired" and finally "worn out" or "exhausted". A very fine example of this is shown in Fig. 4 which reveals the remarkable drop in the productivity of coffee trees in the State of São Paulo, Brazil. While the amount of coffee grown in this area has increased, the yield per tree has been halved in the last 25 years. This decrease in fertility may not be entirely due to a decrease in the micronutrient status of the soils, but research, carried

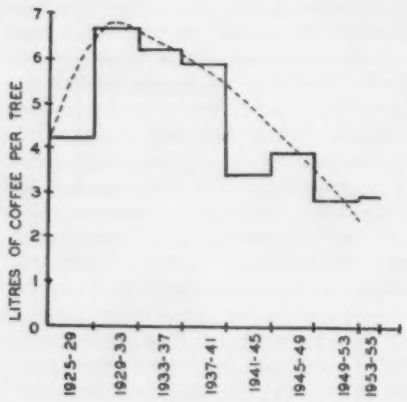

FIG. 4. The average production of coffee, in four yearly periods, from 1925, on the largest coffee plantation in Brazil. During the last 25 years, the yield per tree has been dropping steadily, and increased production has been obtained only by extending the area under coffee. This drop in fertility is probably due, among other factors, to the decreasing availability of micronutrients.

out in the area, shows that micronutrients, especially iron, improves the crop, although no visual deficiency symptoms occur as yet.

Perhaps a more clear cut case of "soil exhaustion" is shown in Fig. 2 B. This was entirely due to lack of micronutrients. When these were supplied, the "exhaustion" was cured very rapidly. Lack of micronutrients was the limiting factor in fruit production.

Micronutrients are of importance in maintaining the physical well-being of soil. The crumb structure of a soil is attributable, among other things, to micro-organisms in it. These micro-organisms have very definite nutrient requirements, and if they are not met, the microbial population of a soil will decrease and loss of such desirable factors as crumb may result.

Latent Deficiencies

Perhaps the most serious aspect of micronutrition is the existence of latent deficiencies. These are deficiencies that are not acute enough to cause easily recognised visual symptoms, but which do cause appreciable decreases in growth. Many workers do not consider these conditions as deficiency diseases. Yet the extent of these deficiencies must be very great, and most deficient areas are surrounded by even larger areas of what is termed relatively poor land, i.e., land on which these latent deficiencies must occur. Nieschlag (22) doubled his crop of potatoes by applying manganese to apparently healthy plants. Roach (29), suspecting what he termed "symptomless disease" to be of importance, increased his yield of wheat grain by 10 cwt. per acre by applying manganese. He is of the opinion that these latent deficiencies are of importance in the south of England and in South Africa. Schütte (33), in a survey of micronutrient deficiencies in Africa, considers latent deficiencies to be of more economic importance than visual ones.

It seems clear that in many areas, especially in damp warmer climates with rapid leaching of the soils, low fertility of agricultural soils must be associated with low micronutrient status. That is, on soils which have received adequate NPK* treatment, as any severe deficiency of the macronutrients will tend to swamp deficiencies of micronutrients.

Ecology

In nature the micronutrient status of a soil functions as an ecological factor. Certain plants grow only under rather specific conditions. Such plants can be used as "indicator plants" and may be of help to people such as prospectors seeking minerals. *Viola calaminaria* Lej. indicates a high zinc content in soils, while *Digitalis purpurea* indicates a high level of manganese (31). The latter is seldom found in Switzerland where high concentrations of manganese are rare.

On so-called deficient soils, a specially adapted flora may flourish. In north Germany on the sandy moor soils, copper deficiency is widespread. The natural vegetation of this region, such as birch and bogwheat, has a very low copper requirement and never shows copper deficiency in the field. But copper deficiency of oats is quite common in the area. This type of soil is frequently used for forestry plantations, but the introduced conifers—*Pinus silvestris, Picea excelsa, Larix decidua*—suffer from copper deficiency because their copper requirements cannot be met by these moor soils (25).

Merkenschlager [cf. Scharrer (31)] is of the opinion that the nutritional requirements of a species indicate the type of habitat in which it originally evolved. Thus iron- and manganese-loving plants, such as rice, oats and spinach, must have developed in areas wholly unsuitable for plants which like alkaline conditions, as under these conditions very little manganese is available. These plants generally have a low manganese requirement and are easily poisoned by it.

Climatic conditions are also of importance, since they influence micronutrients. Plants growing on a given soil may show severe deficiency symptoms in a dry year, while during wet seasons none occur. The water content of a soil appears to influence the availability of its nutrients.

Length of day alters the boron requirement of some plants. Certain soybeans (var. Manchu No. 3 and Biloxi) have a smaller boron requirement under short day conditions than under long (37). High light intensities increase zinc requirement, and zinc deficiency is rare in regions of moderate light intensity (5). In the Amazon Basin this can be quite clearly observed in the forests. The small cocoa trees growing in the shady forests are all normal, but under breaks in the forest canopy, where strong sunlight can reach them, the trees show severe deficiency symptoms (35).

Löhnis (16) reports that at high temperatures beans tolerate a higher level of manganese without toxic symptoms than they do under cooler conditions.

Nutritional Values of Plants

It has been shown that the balance of micronutrients in the soil can influence the vitamin, the protein and the carbohydrate content of plants as well as the total yields. These variations may seriously alter the food value of crops for human and animal nutrition.

Gilbert [cf. Scharrer (31)] showed that the vitamin A content of spinach decreased markedly when manganese deficiency occurred. The relationship between this element and vitamin C and carotene content of plants has been investigated by various workers with conflicting results. This is probably due to the fact that the investigations are not comparable and also because not all plants show the same responses to manganese. Von Bronsart (39) got appreciable increases in the vitamin C content of tomatoes (+ 18%) and black currants (+ 28%) by application of manganese to the soil. Hewett et al. (11) showed that molybdenum deficiency in tomato and five vegetables caused marked decrease in this vitamin, while field trials with complete nutrient fertilizers showed that zinc, magnesium and nickel promoted vitamin C formation in Chinese lettuce, Chinese red peppers and tomatoes (38). Copper increases the vitamin C content of deficient barley, oats and fall-grown spinach but not of tomato or spring-grown spinach (17).

Boas [cf. Scharrer (31)] claims that very low concentrations of selenium increase the vitamin B and biotin content of beans, maize and flax, while Lyons and Beeson (18) showed that very high concentrations of boron and of molybde-

num increased the thiamine and niacin content of tomatoes and turnips.

The protein content of vegetation can be altered by varying the fertilizer practice. Deficiency conditions may even increase the proportion of protein present, and both boron [Jamalainen, cf. Scharrer (31)] and copper (17) deficiencies have been reported to do this. However, the total bulk of protein in human and animal nutrition is not so important as its amino-acid constitution. If a protein is low in essential amino acids, its food value is greatly decreased. Micronutrients influence the nature of plant proteins. Bergh showed that with increasing zinc, tryptophane and tyrosine of barley protein increased, although protein content remained unaltered, while Hewitt, Jones and Williams (10) found that in cauliflower a decrease in molybdenum content results in a large decrease in arginine of the protein. Similar results have been widely reported, and it seems likely that some of the so called protein deficiencies of man and animals may in fact be due to shortages of specific amino acids rather than lack of protein itself. Schütte (34) discusses one aspect of this problem which may be of interest in underdeveloped countries where people live on vegetable diets derived from rather infertile surroundings.

Human and Animal Mineral Nutrition

Both man and other animals have mineral requirements. These must be supplied by the food they eat. For men living in highly developed countries this is not a serious problem, as their mixed diet, consisiting of food from many parts of the world, is usually well balanced. In underdeveloped countries this is not the case and deficiency conditions, which are at present unrecognized, may be quite prevalent. Thus in northern Brazil where the inhabitants are on the threshold of iron deficiency, as one result of a vegetable diet, hookworm anaemia is very prevalent; in the South, where the diet is rich in meat and hence iron, this condition is very much less common, although hookworm infestation is just as great. Cruz (7) cured and controlled this anaemia by applications of iron salts and showed that the anaemia should properly be regarded as an iron deficiency because in the presence of adequate quantities of iron the body can make good the small blood losses from haemorrhages caused by the worms.

Iodine deficiency in man and cattle causes goitre and is easily controlled by small additions of iodine to the diet. Information on this condition, its control and distribution, is abundant and a good world goitre survey exists. It is the best investigated of all the micronutrient deficiencies (13).

Fluorine is apparently necessary for proper development of teeth in humans, where it is required to prevent dental caries. In some deficient areas it is added to the drinking water to ensure adequate supplies in the diet. Excess is detrimental to teeth and is well known in some areas (19).

A micronutrient not required by plants but very important for animals is cobalt. It is part of the molecule of vitamin B_{12} which is necessary for proper production of red blood cells. Ruminants have a very much higher B_{12} requirement than horses or pigs. Cattle and sheep can apparently synthesise vitamin B_{12} if cobalt is included in their diet. In its absence, cobalt deficiency (salt-lick disease, bush sickness, etc.) with its severe anaemia occurs. In simple anaemias of man, which are primarily iron deficiencies, cobalt is frequently included in the medicine with beneficial effects, but in pernicious anaemia the vitamin B_{12} itself must be given.

Iron is necessary for blood formation, but its salts are difficult to absorb. Its deficiency, or near deficiency, is wide-

spread in both man and other animals. Copper is another element which may be dangerously low in many diets (19) and which is associated with blood formation.

Manganese is also necessary in human diet and appears to be of importance in the utilization of vitamin B_1. It is of importance in mammalian reproduction. In Holland manganese deficiency symptoms can be found in young cows [J. Grashuis et al., cf. Scharrer (31)].

Molybdenum is essential for rat development (21) and probably for many other mammals.

Zinc is another element which may be of considerable importance in underdeveloped or poverty stricken areas. It is suspected that the zinc intake in South China is below the threshold value (19), and there is a strong correlation between zinc and vitamin B_1. Hence the food is also low in this. In beri-beri, which is vitamin B_1 deficiency, Eggleton (8) has demonstrated that there is a marked reduction of zinc in epidermal tissues. In heifers absence of zinc is seriously detrimental to reproduction (19).

Disease Resistance

While it seems very reasonable to expect that inadequate nutrition should leave plants more susceptible to infection by pathogenic organisms, this aspect of micronutrition has received little attention. Yet if there is any appreciable increase in disease resistance as a result of proper fertilization, this must be of great economic importance, as the annual crop losses from fungal and bacterial disease are enormous.

Some information is available which clearly indicates that there is a relationship between degree of infection and the nutritional state of the host organism. Sugar beet does not become infected with *Phoma betae* unless it is boron-deficient. Boron-deficient barley is more susceptible to mildew than controls, while boron-fertilized wheat shows increased resistance to *Puccinia triticina* and *P. glumarum*. In sunflower boron increases resistance to powdery mildew, while in linseed it improves resistance to bacterial infection (31).

Russian workers have increased the resistance of wheat to wet smut by addition of boron, copper, magnesium and manganese to fertilizers (20).

Manganese deficiency in oats reduces resistance to bacterial infection, while molybdenum increases the disease resistance of both lucerne and lettuce (31). Silicon, which is not claimed to be a micronutrient, increases the resistance of cereals to mildew, and when its concentration in the plant is low, infection is extremely severe (40).

In animals similar conditions may exist. In the U.S.A., brucellosis has been prevented by feeding a mixture of manganese, copper, cobalt and iodine, while in Germany acute vaginitis in cows was cured by a mixture of cobalt, copper, calcium, manganese, iodine and zinc (31). Deficiencies of copper and iron make swine susceptible to parasitic invasions (1).

In man, copper appears to increase resistance to rheumatism (30). For certain clinical conditions, mixtures of micronutrients are manufactured on a limited scale but their use is not widespread (31).

Physiology

A sound knowledge of the plant physiological role of micronutrients is very desirable, as only with such information will it be possible to prepare fertilizers especially adapted for certain circumstances. It may be very desirable in certain plants to develop the roots at the expense of the tops, for instance. Can this be brought about by altering the fertilizer mixture? The answer is that certainly it can, but our knowledge is too inadequate to allow us to do it for more than one or two plants.

Of the physiological information available, much is of a biochemical nature, especially relating to enzyme activity, that cannot be directly applied to experimental work on entire plants in the field. The influence of micronutrients on important processes such as transpiration is not well studied, but the information that is available is most interesting.

Zinc has been shown to govern the auxin content of tomato and sunflower plants (36). Low levels of zinc give low levels of auxin. This makes the cause of the small leaves and stunted growth, which is usually associated with zinc deficiency, quite clear. It also explains why high light intensities increase the zinc requirements of tissues, as the light rapidly inactivates the auxin in the tissues.

The role of boron has been well studied, although its function in plants is by no means clear. It is the only micronutrient which does not appear to be either an activator or a constituent of an enzyme complex. It seems to be a regulating substance of importance and is found in meristematic tissues. Its deficiency causes abnormal meristematic and cambial growth. Deficiency frequently blocks or retards translocation of carbohydrates from leaves, and absence of boron prevents pollen germination in many plants (31).

In legumes increased boron applications induced a type of xerophytism, causing increased transpiration under moist conditions and less under dry (31). Schmied (32) studied the effect of boron, copper, zinc and manganese on the water economy of a series of plants and found that in general these substances improve it. This effect, especially since these nutrients frequently promote better root development, must be of great importance in arid and semi-arid regions where increased water economy may be of survival value. Arland's work on nutrition and water economy is also enlightening in this respect (2).

Molybdenum deficiency appears to make lucerne more susceptible to cold, and small quantities of copper apparently greatly increase the cold resistance of cereals (31).

The influence of micronutrients upon respiration appears to vary considerably, and the same is true of carbon assimilation. The latter may at first seem surprising as many deficiency conditions are characterised by chlorosis, but it must be remembered that in many plants, chlorophyll content is not the limiting factor in carbon assimilation.

The alterations in anatomy caused by deficiencies may be very characteristic, and both Reed's (26) work with zinc and Löhnis' (15) work on boron are of great interest. In general, however, this very interesting field of investigation has not yet been well studied.

Gymnosperms and Cryptogams

The micronutrition of these plants, with the exception of fungi, has not been studied to any extent. This is unfortunate in as much as conifers are of great economic importance and are frequently grown on poor soils which may be deficient in micronutrients. In West Australia zinc deficiency in pine plantations (*P. radiata* and *P. pinaster*) occurred on a large scale (24), and Wilson (42) observed a similar condition in the U.S.A. in *P. echinata* and *P. taeda*, while Rademacher (25) in Germany showed copper deficiency in pot experiments.

Culture work in the laboratory has made it necessary to study the mineral nutrition of both small algae (23) and the fungi. With the latter it is of interest to note that zinc deficiency induces a high production of certain acids, for instance, lactic, glutaric and citric (5). This type of reaction can be of industrial importance.

Distribution of Deficiencies

The distribution of micronutrient deficiencies is very wide and constitutes a grave agricultural problem, but no accurate world surveys have been undertaken. This is most unfortunate, as without adequate surveys the gravity of the problem cannot be accurately assessed. Thus many people are still of the erroneous opinion that these deficiencies are not of great economic importance, except locally.

This opinion is quite false. While much valuable unpublished information is still stored in agricultural stations and much published work available has not been co-ordinated, the surveys which have been conducted show the world-wide distribution of these problems.

A world goitre survey (13) shows the world-wide distribution of iodine deficiencies, while animal deficiencies were mapped by Allman and Hamilton (1). Schütte (33) attempted to map the known plant deficiencies in Africa and showed the wide distribution there. He found that similar conditions prevailed in Brazil (unpublished). Conditions in Australia are definitely similar, although there are not any continental surveys. In the U.S.A., Beeson (3) mapped the known deficiencies and showed their wide distribution. In Europe deficiencies are being reported with increasing frequency. Information about conditions in Asia is very scarce, but it can be assumed that these deficiencies occur on just as large a scale there. Existing information very strongly suggests that these conditions are of world-wide occurrence and of considerable economic importance.

In general, it can be stated that acid soils, especially in the tropics, are easily leached and thus may frequently give rise to deficiencies, while alkaline soils are not so easily leached but micronutrients tend to be present in unavailable form in them. The degree of weathering of a soil will govern the amount of micronutrient present, and so igneous rocks tend to be low in micronutrients. Very tentatively it may be said that modern mixed soils derived from different geological sources, such as boulder clay or loess, tend to have a balanced micronutrient status if they are not excessively leached. Those are the soils of the better agricultural land in the temperate portions of Europe and North America. In the mountainous regions of Europe, or on the humus sands of the North German Plain, deficiencies are widespread. The rapidly leached and eroded soils of the tropics and semi-tropics should and do show these deficiencies extensively. In these regions full fertilization should be the goal of agriculturalists. They should aim at supplying all the essential nutrients, both macro and micro, in all their fertilizer programmes. This should be regarded as normal procedure in these regions. NPK fertilizer trials may give very misleading results.

Discussion

From a consideration of the available evidence it would appear that the role of micronutrients in nature is generally underestimated. While they are not substitutes for the macronutrients, it is essential that they be considered in fertilizer programmes in many parts of the world, especially in warmer moist climates. Fertilizers should aim at supplying the essential nutrients required by plants, and for an efficient and economic use of fertilizers both macro and micro nutrient requirements must be met. Otherwise low concentrations of some element will function as a limiting factor and seriously reduce crop production.

The possibility that water economy and the nutritional value of plants can be greatly influenced by the supply of

nutrients is of great importance to agriculture, especially in many undeveloped countries, and the possibility of combatting infection by adequate nutrition is of great potential value in preventative plant pathology, as even today vast quantities of foodstuffs are lost annually to micro-organisms.

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Utilization Abstract

Guar. A recent product from an old African-Indian crop has found many new uses. Guar gum, a colloid with unique properties, is extracted from the endosperm of the seed of *Cyamopsis tetragonaloba*, a member of the Legume family. Produced by Stein, Hall & Co. as JAGUAR, guar gum is a complex carbohydrate polymer of galactose and mannose, chemically classified as galacto-mannan.

The properties which make guar gum useful in mining (as a flocculent and filter aid), in drugs (as an appetite depressant), in cosmetics (as hand lotions, washable creams), in paper manufacturing, in the food industry and others are: high viscosity at low concentrations; cold water swelling; usefulness over a wide pH range; excellent thickening, film-forming and stabilizing properties; flocculating and filter-aid properties in trace quantities. The original use of the plants in this country was founded on their soil-building qualities; they were introduced for this purpose into Arizona in the 1900's.

The plant is grown as an annual summer crop on sandy loams and lighter soils, setting abundant seed in more arid areas under irrigation. In humid areas, seed production is delayed, and rain at time of maturity is destructive to production of the gum. The major areas of best growth occur in Texas (Wilbarger County), with southern Arizona as another possibility if irrigation is provided. The major geographical sources of guar today are Pakistan and India.

An important harvesting problem is caused by the easy dropping-off of the pods before the plants are cut and dropped onto the apron of the combine. No major insect pests attack the crop, but the plants need careful weeding as they do not compete well against several common weeds. (Herbert Goldfrank, *Chemurgic Digest 16(2–3): 10. 1957*).

Charcoal—*Its Manufacture and Use*

Charcoal is the most ancient of manufactured plant products, dating from early prehistoric times. Today about 375,000 tons are annually produced in the United States, to be used not only as fuel but also in the metallurgical industry and as a chemical raw material. Both hardwoods and softwoods are converted into it.

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Introduction

The charcoal industry provides a positive means for large-scale utilization of forest and mill residues. The place of this industry as a silvicultural aid in forest management cannot be over emphasized.

Processes are available for handling either large quantities of raw material from extensive integrated operations or limited amounts from small farm woodlots. A market for second-growth stand-improvement cuttings that are not suitable for other uses can be provided. Because of this scavenger-like nature, cull logs, tops and limbs discarded in logging and cutting operations provide the chief source of raw material. Other types of suitable raw material include mill slabs, edgings and larger block sections. Sawdust, shavings and similar wood fines are being commercially converted in only limited quantities because of processing and economic obstacles not yet entirely overcome. These latter kinds of wood residues are potentially, however, an abundant and relatively cheap source of raw material for future large-scale conversion.

Both hardwoods and softwoods can be used for raw material. The availability and practical worth of such hardwood species, beech, birch, maple, hickory, sweetgum, ash and oaks, make them generally preferred for chemical conversion. Similarly, among the softwood species, the old stumpwood from longleaf and slash pines is preferred because of availability and its high resin content.

An outline of domestic charcoal production would include, chronologically, use of the primitive dirt or sod kiln (2, 16), the brick beehive kiln, the small retort of 50 to 75 years ago, and the present concrete-block and sheet-metal kiln structures, ovens and vertical-tube retorts. More efficient processing has accompanied these steps, as a rule, both within the scope of the kiln operations that produce only charcoal, and the chemical plants that recover charcoal and associated byproducts. Current charcoal production still represents a cross section of all of these methods. Progressive improvements in methods and operational control account largely for any significant differences that may be present in the uniformity or properties of the charcoal obtained from kilns and from recovery plants.

Some properties of the wood itself, regardless of the method applied, are directly related to those of the resulting charcoal. The hardness and density of maple, oak and hickory are readily apparent in the charcoal they produce, as

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

FIG. 1 (Upper). Early dirt charcoal kiln in process of unloading or "drawing". "U. S. Forest Service".

FIG. 2 (Lower). Brick beehive kiln—large scale kiln conversion of wood wastes to charcoal.

are the relative softness and light weight of charcoal from willow and alder. The bark of many hardwoods is quite dense and rich in carbon, and would be expected to yield as much charcoal as an equal weight of the clear wood. Among the softwood species, this condition exists to a lesser degree. Aside from a few types of charcoal that have specific properties that meet the needs of specialty use, all, in general, satisfy the usual market requirements. Charcoal of good quality has a fixed carbon content of 78 to 82 percent (8).

Production in Kilns

Formation of charcoal by "burning" takes place when wood is heated in a kiln in the presence of regulated but limited amounts of air. The initial heat required to start the process of wood drying and decomposition is supplied by igniting part of the charge. Retarded combustion, or coaling, proceeds with air added in sufficient amounts to maintain a glowing progressive fire zone throughout the charge. Volatile products formed by combustion and distillation of the wood escape through stacks or directly from wall ports. The charcoal, usually with small amounts of ash, remains as the residue.

Numerous kilns of both fixed and portable design (1, 4, 5, 15) have been developed and operated commercially in accordance with the general principle described. In the forming and operation of earth kilns, important considerations are wood accessibility, sheltered location and character of soil. Sound, seasoned hardwood pieces, about four feet long and six to eight inches in cross section, are usually piled in mounds of as much as 50 to 90 cords. A substantial layer of earth is placed over the wood to provide an enclosure. A period of about 20 days is needed to convert a wood charge of 50 cords by this method. Yields of 700 to 750 pounds of marketable charcoal per cord are obtained. Despite the reduced yields expected from kilns of this type, a low initial investment gives a favorable effect for limited current production.

Another type of kiln used since early days is the so-called "beehive" (10) brick unit. Kilns of this design provided more efficient operation and production of greater amounts of carbon required for early charcoal-iron manufacture. Beehive kilns now in use include both very old and fairly recent units of typical construction. Old ceramic kilns of the same general design have been converted to charcoal production. These kilns are roughly dome-shaped and range in capacity from 50 to 80 cords of forest or slab wood. Most beehive installations operate with from three to 18 units. Each kiln represents an estimated investment of $6,000 to $8,000. About 800 pounds of marketable charcoal and 50 pounds of unsalable fines per cord of dry wood are obtained on the average. These fines may subsequently be made into briquettes at charcoal-producing plants with briquetting facilities or at other briquetting plants.

Considerable progress has been made in the development of small concrete-block kilns. Numerous kiln installations of this general type are commercially producing charcoal with satisfactory results. Their advantages are comparatively low investment per cord of capacity, simplicity of construction, and favorable charcoal yields. The investment required for concrete-block construction is estimated at $125 to $150 per cord of capacity. Controlled operation in such equipment gives charcoal yields of about 900 pounds, 750 pounds, and 650 pounds a cord from, respectively, the denser seasoned hardwoods, green hardwoods and softwoods. Sizes of these kilns are generally from two to ten cords.

FIG. 3. Brick, beehive type, kiln. Large-scale kiln production of charcoal in converted ceramic kilns.

Production in Hardwood Byproduct-Recovery Plants

Nearly half of the nation's charcoal output is from a group of six hardwood distillation plants located chiefly in areas with stands predominately of maple, birch, sweetgum and oak. These plants also include facilities for the recovery of acetic acid and methanol. Production is conducted in part by conventional oven carbonization and by other carbonization methods quite different in principle and application. All plants have in common, however, two main operating steps in which (*a*) the wood is predried and carbonized and (*b*) the crude liquid products obtained are refined.

Oven Processing. The conventional oven operation is a batch process. The sheet-steel ovens hold approximately ten cords of cord-size wood. The ovens are commonly set in pairs, and heat is applied externally from separate fire boxes. Steel rails on the floor of the oven and in line with yard and cooler tracks allow fast charging and discharging of the ovens by means of steel buggies. Full cross-section swinging doors at both ends of the oven are made gas-tight with steel wedges that engage the door frame. Excessive heat radiation is prevented by an additional outside door. Distillation volatiles leave the oven through sidewall vapor take-offs to water-cooled copper condensers.

Coal and manufactured and natural gases are the chief fuels used for firing. Controlled heating of the ovens to an end temperature of about 800° F. assures optimum yields of low-volatile charcoal and refined liquid byproducts. Distillation cycles vary from 18 to 22 hours and may be so timed that charging and discharging of a number of ovens can be accomplished at staggered intervals. The hot charcoal is withdrawn to gas-tight, sheet-steel coolers at the same time a new charge of wood enters the ovens from the yard or from predriers. A minimum time of 48 hours in the coolers and 48 hours in covered sheds is required for conditioning the charcoal before it is shipped. From 1,000 to 1,100 pounds of charcoal is generally obtained from a cord of wood in oven processing.

Stafford Retort Processing. The Stafford retort (9) has little resemblance structurally or operationally to the conventional ovens. Processing in this type of unit is continuous. Wood that has been hogged or is in small blocks or chips is utilized, rather than cord or long block lengths. Production in one domestic plant started almost 30 years ago and has since been maintained continuously. It is of interest to note that where low-cost scrap from an adjacent mill initially provided all of the raw material, the greater part now required is from forest hardwoods and sawmill residues.

Efficient predrying and related low moisture content of the wood are important factors to the Stafford carbonizing operation. The wood from the rotary driers is fed to the retorts at a predetermined rate and at a moisture content not exceeding 0.5 percent. Flue gases from the power plant supply the heat to the predriers supplemented by non-condensable wood gas.

The Stafford retort operates vertically, is about 40 feet high and ten feet in diameter, and is heavily encased overall with insulation. Adequate provision against heat losses must be made, since a critical heat balance within the retort is a controlling factor for proper operation. Automatic barrel-type valves at the top and bottom ends of the retort prevent the introduction of air with the wood feed, and also prevent the escape of volatiles at these points. The preheated wood enters the retort at a temperature of about 300° F. As the wood continually moves downward, carbonization conditions are maintained by utilizing reaction heat available at about midpoint in the retort. The average tem-

FIG. 4. Sheet metal kilns, operating battery-wise near mill slab waste supply.

perature in this central zone is about 950° F. and gradually decreases with charcoal formation to about 480° F. at the base. Volatile materials pass from outlets at the top of the retort to four evenly spaced condensers. The charcoal is discharged continuously to air-tight coolers and conditioners. The small-size charcoal produced has restricted markets as such, but, on the other hand, needs only limited grinding for briquette production. About 1,000 pounds of charcoal are obtained from each cord of wood. The entire output of about 130 tons of charcoal per day is converted to briquettes. An additional plant using the Stafford principle has recently been reported under construction. This plant is estimated to cost two and a quarter million dollars and will utilize woods and mill residues in chipped form.

Converted Hardwood Byproduct-Recovery Plants. Some of the more marginal plants have been forced by economic conditions to curtail full byproduct manufacture to the recovery of charcoal alone. Such retractive measures have resulted in better plant returns, and better plant position for future charcoal production.

Conversion of these plants is accomplished by eliminating the highly specialized equipment for the recovery and refining of the liquid byproducts and leaving intact the carbonizing facilities. The change-over from full recovery processing is quite simple and requires only that the retort gases be vented from the condensers to the atmosphere, to an outside combustion furnace, or to the oven fire boxes for use as supplementary fuel. Either of the latter two means for disposal of volatiles is preferred, since direct bleeding to the atmosphere may create both a nuisance and a possible health hazard. Charcoal yields comparable to those from oven byproduct plants are obtained, and at reduced cost.

Gas-Circulating Processes. A marked change from conventional oven-carbonization methods is evident in the more recent commercial techniques developed in Germany by Reichert (7, 11, 12) and in Belgium by Lambiotte (6). These techniques may help overcome the persistent economic barriers of high wood and labor costs in the United States. One large oven plant has already been partially converted, and full conversion of another is contemplated.

In principle, the carbonization methods employed by Reichert and Lambiotte are similar, but they differ from other systems in that they use a hot, inert gas media for transfer of heat to the wood. Although the Reichert operation has been essentially batchwise and that of Lambiotte continuous, it is reportedly possible to make the Reichert process continuous without undue difficulty. With the further exception that the heating gas in the Reichert retort flows downward with the direction of the wood through the retort, and countercurrently to the wood travel in the Lambiotte retort, both methods may be described briefly together. The retorts are cylindrical with conical end sections, and are mounted vertically as individual units or in batteries. Both top and bottom sections of the Lambiotte retort are equipped with special valves to permit loading and discharging without intake of air or loss of wood gases and vapors. In operation, heated wood gases enter the retorts through valved openings, spread throughout the charge, and are subsequently emitted along with distillation vapors to condensers. A portion of the dried gases from the condensers is blown under slight pressure through furnace tubes and is heated to a predetermined temperature by combustion of the remainder of the condenser gases. Passage of the heated gas from the furnace to the retort completes the cycle. Conditions of gas recycling and circulation within the retort

FIG. 5. Sheet metal kilns, readily portable for location at various sources of wood supply.

are automatically maintained with a minimum of attention. The yield of charcoal per cord is comparable to that obtained by other commercial processes with similar hardwood species. As yet, domestic charcoal production from this type of operation is limited.

Production in Resinous-Wood Byproduct-Recovery Plants

At the outset, the recovery of charcoal at resinous-wood byproduct-recovery plants was of secondary importance, marketwise, to the recovery of the distillate containing pine tars and oils. While both products are now equally important, the nature of the raw material that must be used restricts location of the plants to areas of abundant supply. These areas contain the desired "pitchy" stumpwood from old, logged-over southern pine stands, and are confined chiefly to the region along the Gulf Coast. Unlike the perpetual supplies of raw material that are available for plants in the hardwood-distillation group, progressively decreasing supplies are generally the outlook for resinous-wood operations. On the basis of proportionate plant return, charcoal has become increasingly important, however, and might make possible the use of softwood raw material now considered inferior.

Southern stumpwood is generally carbonized in batches in horizontally mounted, cylindrical steel retorts (3). Fire boxes are located at one or both ends of the retort, depending upon its length. In a few operations the retorts are sufficiently large for car loading, but most are charged and discharged by hand. Two plants vary the process by using concrete retorts with inside flue-pipe heating. Processing has been further varied by not heating the bottom of the retort, so that much of the higher boiling liquid can be drawn off at the bottom and vapor fractions can be passed through side outlets to condensers. Other than for the oil heating applied to the concrete retorts, firing methods are similar to those used in the hardwood-distillation industry. The charcoal is removed to an air-tight receiver after it has been heated for about 24 hours. It is then put in open-shed storage.

Status of the Carbonization Industry

The annual charcoal production in the United States is currently estimated to be 375,000 tons. Table I shows the estimated annual production of charcoal by process classifications, with the corresponding amounts of raw material consumed.

TABLE I

ESTIMATED ANNUAL PRODUCTION OF CHARCOAL

Plant process	Charcoal produced	Wood consumed
	Tons	Cords
Kiln	125,000	275,000
Hardwood—byproduct recovery	160,000	325,000
Hardwood—converted byproduct recovery	23,000	46,000
Resinous-wood byproduct recovery	67,000	134,000
	375,000	780,000

The carbonization industry has a less favorable economic condition now than about 25 years ago. In the intervening period, wood costs have more than doubled, and labor costs, on the average, have increased to at least an equal or greater degree. Charcoal prices, however, did not increase proportionately. In the mid 1930's, upwards of 50 recovery plants were producing charcoal. The present recovery-plants, all of which have fixed locations and potentially unfavorable wood costs, now provide the bulk of the charcoal. Because it would cost an estimated $25,000 per cord of capacity to construct a new hardwood recovery plant, it cannot be foreseen that any large or continued expansion of the

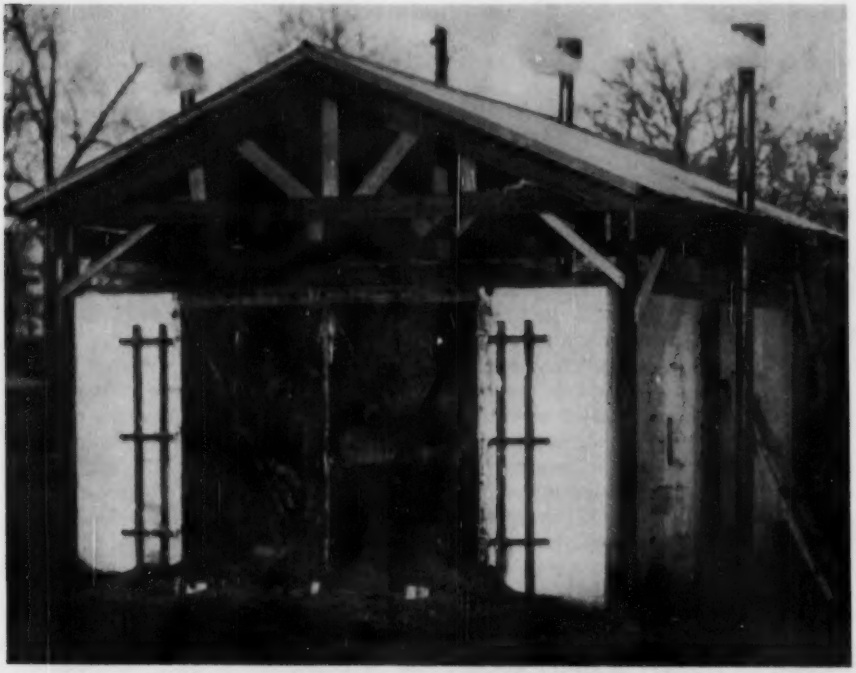

FIG. 6 (Upper). Two-wall, 7-cord, masonry block kiln—a recently developed unit providing features for operational efficiency and increased uniformity of product.

FIG. 7 (Lower). Commercial 9-cord, concrete block kiln—both large and small units are operated singly or in groups to provide flexible charcoal production amounts.

charcoal industry will take place in this conventional manner.

Utilization of wood residues for charcoal cannot be overlooked, even though past commercial efforts have been largely unsuccessful. Mill refuse can be made available for conversion at a cost considerably below that of forest wood, and is available now at a cost of about only one-half that of forest wood. Satisfactory commercial conversion in the past has been retarded primarily because of excessive equipment and maintenance costs and the lack of markets for small particles of charcoal. More recent developments in this field indicate that mill residues can be utilized in practical operations. One of these developments is a semi-commercial unit (13) designed at the Oregon Forest Products Laboratory, Corvallis, Oregon, and constructed to operate on Douglas-fir mill fines. This unit includes the essential factor of continuous feed input, and has been further designed for recovery of all the byproducts. Briquette research was carried on at the same time in order to establish the practicability of a combined operation.

Other carbonization research on wood-waste fines includes the application of a fluidized-bed technique. In this method wood particles are continuously fed to a cell containing inert gas as a heating medium. The particles are kept agitated by controlled input and upward movement of the gas stream until they are completely converted to charcoal. The results of exploratory investigations conducted at the Georgia Institute of Technology, Atlanta, Georgia, the Oregon Forest Products Laboratory, Corvallis, Oregon, and the Stanford Research Institute, Stanford, California, indicate promise for commercial expansion of the fluidized-bed technique in the future.

Still further studies in the field of fine wood-particle carbonization are those relating to the so-called Phillipson continuous process, which has been tried at Eugene, Oregon, and the continuous liquid bath process (14), carried on at the U. S. Forest Products Laboratory. In the Phillipson retort wood fines are fed continuously by screw conveyor into the topmost of a series of horizontally mounted steel tubes connected at alternate ends with vertical-tube risers. Screw conveyors at alternate ends of the externally heated tubes provide progressively downward flow of the material. Charcoal is discharged at the bottom tube outlet.

In the liquid bath type of operation, extremely rapid heat transfer is possible by complete submersion and continuous passage of wood fines through molten metal. The possibility of secondary reactions is minimized by the removal of condensable byproducts as they are formed. Charcoal is withdrawn continuously from the discharge end of the distillation bed. In these latter investigations especially, fundamental research on relationships of time, temperature and rates of decomposition are necessary.

Utilization

During the past several years, charcoal markets have been increasingly active, with demand oftentimes exceeding production. Charcoal is both a chemical raw material and a fuel, and its consumption in these two major fields determines the operational pattern of the industry. Uses of charcoal in metallurgy and in associated applications can be rated considerably less important. Charcoal is consumed in the form of lumps, briquettes, screenings, powder and activated charcoal. It is used primarily as domestic and specialized fuel, and in the metallurgical, chemical and allied fields. The market for charcoal as a recreational fuel is tremendously active. These uses, without relation to individual tonnage consumption, are shown under three groupings in Table II.

Despite the widely different produc-

TABLE II

USES OF CHARCOAL

Domestic and specialized fuel	Metallurgical	Chemical
Recreational	Copper	Carbon disulfide
Curing tobacco, meat, and fish	Brass	Calcium carbide
Heating and cooking in dining cars	Pig iron	Silicon carbide
Heating foundry, tinnery, and plumbing equipment	Steel	Sodium cyanide
	Nickel	Potassium cyanide
Heating houses, laundries, and incinerators	Aluminum	Carbon monoxide
Heating salamanders in shipyards and citrus groves	Electro manganese	Activated carbon
	Armor plate	Black powder
	Foundry molds	Electrodes
		Fire works
		Catalyst reactor
		Rubber
		Brake linings
		Molding resins
		Gas-cylinder absorbent
		Paint pigment
		Crayons
		Nursery mulch
		Pharmaceuticals
		Poultry and stock feeds

tion processes, the product is surprisingly uniform in properties, and rigid consumer specifications are not generally required. Its marketability for industrial and fuel uses is determined by its bulk weight and percentage of volatile matter. Limiting maximum values for volatiles and moisture content are about 20 percent and two percent, respectively.

There are economic limitations associated with further expansion in the recovery-type operations. It is apparent that additional facilities for charcoal production will stem largely through the development of processing equipment for wood fines and the more extensive application of kiln operations for forest and heavy mill residues. As waste utilization tools, their wide development would afford excellent opportunity for greater and cheaper production.

Despite the existing favorable aspects of kiln production, research in this field could be gainfully applied. Kiln production provides a means of immediate money return to the farm woodlot owner, and industrial opportunities for others interested in comparatively large-scale production. Additional basic information relating to kiln structural performance and elements of operational control is needed, however. Field kiln studies are being conducted by the U. S. Forest Products Laboratory in cooperation with associated Forest Experiment Stations. The results are expected to provide a more adequate guide for technical and economic development and commercial expansion of this method of wood-waste conversion.

Kiln operations strategically located with respect to wood and charcoal markets already produce substantial tonnage. It is not difficult to forecast that, with additional similar facilities, production could be expanded almost at will. However, it would seem desirable in this event that production stabilize itself around a lower-priced material. A trend in this direction would relieve a growing danger of charcoal pricing itself off the market, and also establish a position for retaking a number of outlets now lost to cheaper carbons.

The wood carbonization industry as a whole will no doubt operate with a meas-

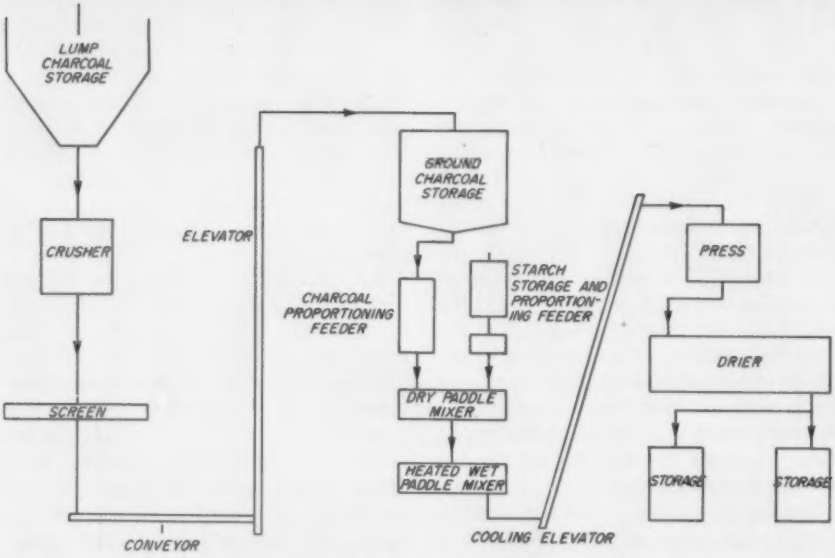

FIG. 8 (Upper). Hardwood by-product recovery plant—includes carbonization and refining facilities for the production of chiefly acetic acid, methanol, and charcoal in lump, briquette and activated forms.

FIG. 9 (Lower). Flow diagram. Commercial process for the manufacture of charcoal briquettes.

ure of profit for some time to come. It will expand, however, only through further technological and economic research in connection with existing production techniques and in the development of more suitable ones as well.

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Utilization Abstract

Pine-gum Research. The U. S. Department of Agriculture Naval Stores Research Station, Olustee, Fla., is active in the study of methods of production and new products from pine-gum. One of the outstanding improvements in production methods of turpentine and rosin worked out by this station is the continuous distillation process which saves about half the steam needed to operate batch stills.

Research on derivatives of crude pine-gum has shown that maleo-pimaric acid is valuable in industrial applications as printers' ink, paper sizing, alkyd resins, and photographic chemicals. From turpentine, preparations of esters of pinic acid are excellent lubricants for engines of jet aircraft; as additives to plasticizers, these esters give to plastics the desirable qualities of low temperature flexibility, durability and permanence. Pinane hydroperoxide, derived from turpentine, is useful as a catalyst in the production of cold rubber.

From rosin, with the addition of lead and magnesium to aldehyde-modified rosin, improved metal resinates are produced, with good paint-drying qualities. A new acid has been discovered in rosin, resistant to crystallization. Palustric acid, first identified in *Pinus palustris*, has already found use in paper sizing, and has promise of other indusdustrial utilization. (Anon., *Chemurgic Digest 15(10): 4–5. 1956*).

The Introduction of Date Palms into Baja California

Customary accreditation of 1730 as the year of introduction of date palms into Lower California is a literary invention. More acceptable evidence places the event in 1765 or thereabout.

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At several oases in the south central part of the peninsula of Baja California, date palms (*Phoenix dactylifera*) constitute the principal agricultural resource. Seen from the surrounding barren hills, or mesas, the settlements at San Ignacio, Mulegé, Loreto and Comondú seem to be forests of the dark green palms. Closer observation exposes an understory of irrigated cultivation of the fruit trees, shrubs and annual crops. The initial appearance of the oases, though not the indifferent cultivation practice, recalls the oases of the Old World. The date palm also figures prominently in such farming as is done in a dozen other small centers of cultivation in this dry and sparsely settled region.

The problem of when and how this Old World tree crop was introduced into this appropriate New World environment has provoked comment from several recent students of the history of Baja California. Unfortunately, the frequently repeated statement that the Jesuit missionaries brought in and planted three Arabian varieties of dates in San Ignacio in 1730 seems to be founded on literary invention instead of fact. As a recent example, Father Peter J. Masten Dunne, the noted Jesuit historian, makes this statement in his comprehensive history of Jesuit activities in Baja California without citing a source (3). The implication is that the early introduction of date palms by the Jesuits is general knowledge. After a rather exhaustive examination of both published and manuscript literature on the history of Baja California, I am prepared to say that this statement on the introduction of date varieties first appears on page 34 of " Mother of California " by Arthur W. North, one of the first and most popular of an ever-broadening stream of travelogue histories of Baja California. Though North states that he examined old manuscript records concerning the peninsula, some of which may well have been destroyed in the San Francisco fire of 1906, it is unlikely that there were any materials which antedated 1769, the year the Franciscans entered California. North was inventing a plausible and romantic story to account for an obviously long established horticulture which characterized a group of settlements he knew to have been founded by Jesuit missionaries.

To the best of my knowledge, dates are referred to only once in all the contemporary Jesuit literature. Father Johann Jakob Baegert, a Jesuit expelled from the peninsula in 1768, mentioned dates in a list of minor crops introduced by the missionaries (1) [1]. Since he discussed most of the introduced crops at the missions at some length, it must be

[1] The original German edition of this work was published in Manpheim in 1772.

FIG. 1 (Upper). Date palms at the oasis of Mulegé on the east coast of Baja California.
FIG. 2 (Lower). Date garden at San Ignacio. Note the variable age, the random distribution of the trees and the many volunteer seedlings.

assumed that dates were a very recent and minor introduction. Probably none of the plants had borne fruit by the time the Jesuits were expelled.

In an exhaustive inventory of the missions, written in 1774 (6) by the Dominican missionaries who had succeeded the Franciscans the preceding year, the presence of three date palms at Comondú is mentioned. The accords with Baegert's bare mention of the plant. If they had been young seedlings in 1768, they would have begun producing, but no extensive plantings could yet have been made. The first reference to real production of dates comes from San

Ignacio in 1785 (7). In that year that mission produced 20 *arrobas*[2] of dried dates. The same source describes a rapid increase of date production at San Ignacio to 200 arrobas by 1800. Though no record has been found, it is likely that comparable quantities of dried dates were produced at Comondú, Loreto and Mulegé during the same period. By 1857 the municipality of Mulegé, which included that city and San Ignacio, was producing 3000 arrobas (5). Modern date production at San Ignacio is estimated at 200 tons, or 16,000 arrobas (9), and an only slightly smaller quantity is produced at Mulegé.

Increase of production from the late eighteenth through the nineteenth century was steady and roughly logarithmic. Modern cultivation practices would indicate that the growth of the groves was a matter of volunteer seedlings establishing themselves in moist arroyo bottoms which saline soils rendered relatively unsuitable for most other crops. Probably by 1900 date palms had occupied about all the areas suitable to them, and expansion of the groves ceased.

Though the time of introduction of dates to Baja California has thus been established with fair precision, the specific source of the plants brought in and whether they were seedlings or varietal offshoots is not known. Present day cultivation is strictly of seedlings and is casual indeed. Practically no effort is made even to reduce the proportion of non-productive male trees. Consequently there is no possibility of identifying clone varieties of known origin. There is no mention of varieties of dates in any of the mission literature, though the same literature does refer to clone varieties of grapes and figs. While date offshoots undoubtedly could have endured the trip from North Africa to the East Coast of Mexico by the eighteenth century means of transportation, the overland and sea journey across Mexico and on to Baja California took additional months. The possibility of keeping offshoots viable for the entire trip was exceedingly small. Plantings of seeds are much more probable.

Seedling date palms are so heterogeneous in the character of their fruits that the actual original source of the seeds of the Baja California date groves has only historical interest. The relatively low quality of the modern fruit is a natural product of any series of generations of volunteer seedlings, regardless of where the seeds came from. Three possible sources of the seeds suggest themselves. Dates have been raised at Elche in southeastern Spain since Moorish times. These palms are mostly seedlings, and male trees are almost as numerous as female. For climatic reasons the date yield could not be very satisfactory, and sale of leaves for religious decoration on Palm Sunday seems to be about as important as fruit production. The casual date culture of Spain is certainly reminiscent of that of Baja California, though in the latter place climatic conditions would justify more careful attention to the groves. A second source for date seeds, of course, is the fairly extensive Spanish trade with nearby Northwest Africa where the fruit has long been a major article of commerce. Finally, dates may have been a secondary introduction from the coastal desert of Peru. This region possesses a climate which is entirely appropriate to date culture, and there are now some palm groves though they do not constitute a major crop. To the best of my knowledge the time of introduction of palms in this region has not been investigated, but Peru was intensively exploited by the Spaniards more than a century and a half before the first settlements were established in Baja California. A fairly steady trade between Mexico and Peru operated in the six-

[2] The arroba is a measure of weight roughly equalling 25 pounds.

teenth and seventeenth centuries (2). It may also be noted that modern date cultivation practices in Peru resemble closely those of Baja California (4), and a modern introduction from there would certainly be in the form of seeds rather than of offshoots.[3]

The low level of care received by the date gardens of Baja California is symptomatic of the minor interest in agriculture in that region. The owners of agricultural land are few and generally persons of relatively great wealth. A garden means prestige, and dates will grow wild in arroyo bottoms where the water table is high, require little investment in labor, and yet yield a modest return. Braceros returning to Baja California villages from the Coachella Valley tell of the better quality fruit and higher productivity of the date gardens there, but they have never persuaded the local owners to undertake the investment of adopting the higher standards of cultivation.

The commercial date plantings of the California and Arizona desert, though only a few hundred miles away and established after the Baja California groves had attained roughly their present extent, seem to have had no historic connection with their southern neighbors. This fact can be considered as fortunate. Although the first successfully propagated dates introduced into the United States in 1890 may not have been the supposed varieties, the intent was to bring in desirable offshoots. Most of the offshoots selected and shipped by Walter T. Swingle from Algeria in 1899 proved to be the sought Deglet Noor and Rhars varieties. Subsequent commercial and U. S. Department of Agriculture imports attempted to introduce all the desirable established varieties grown from Morocco to the Persian Gulf (8). The standards of cultivation in the United States are based on, and developed from, the most advanced systems worked out over millennia in the Old World dry lands. It is doubtful that Baja California can make any contribution to the United States date industry, but it might greatly increase the production and improve the quality of its own date gardens by adopting some of the cultivation techniques practiced in California and Arizona.

[3] There is a curious and completely isolated reference to the introduction of date palms from Spain into Central Mexico in a book written between 1536 and 1541: Francis Borgia Steck, *Motolinia's History of the Indians of New Spain*. Academy of American Franciscan History, Washington, D. C., 1951, p. 276. Motolinia states that the date-bearing palm trees began to yield fruit a short time after they were planted; he does not say where. No part of Mexico then under Spanish control was at all suitable for date production; it is likely that this attempted plant introduction failed long before Baja California was colonized successfully. Since Motolinia speaks of the fruits of several species of native American palms as dates, he may even have been referring to an introduction of *Phoenix canariensis*, a palm with wider climatic tolerance than *Ph. dactylifera*.

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Indian Jasmine

Three of the eleven species of jasmine commonly cultivated in India are the principal sources of jasmine perfume, widely used in the manufacture of hair oils.

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The Species

Because of their unique, mild and pleasing odour, jasmine flowers (Fam. Oleaceae) have long been valued in the manufacture of perfumes. Every high-class perfume has a touch of jasmine. About 100 species are known, natives, for the most part, of Arabia, China, Egypt, India and tropical regions of the eastern hemisphere. The species commonly grown in India are:

Jasminum ajonicum	*J. officinale*
J. angustifolium	*J. pubescens*
J. arborescens	*J. revolutum*
J. auriculatum	*J. sambac*
J. grandiflorum	*J. undulatum*
J. humile	

For perfumery purposes, *J. ajonicum* (bela), *J. sambac* (moghra), *J. auriculatum* (juhi) and *J. grandiflorum* (chameli) are grown in Uttar Pradesh at Kannauj, Ghazipur, Jaunpur and Ballia. The flowers are used in India for making attars and perfumed hair oils, but not for commercial extraction of their oils. *J. ajonicum* and *J. sambac* are similar in odour but differ in the number of petals. In foreign countries, where absolutes, concretes and oils are produced, the blossoms of *J. grandiflorum* alone are utilized. The three principal species of industrial value are:

Jasminum auriculatum

NOMENCLATURE. "Mugdhee" and "juhi" in Hindi; "gunica", "yodthika" and "umbastha" in Bengali.

DISTRIBUTION. Native to various parts of India as well as Ceylon, Siam, Mauritius and the Deccan Peninsula, but not common in the latter four regions.

HABIT. Erect, woody, branching shrub.

LEAVES. One-half to one inch long; exstipulate; oval; opposite; glabrous; base pulvinous; apex acute; margin entire; venation reticulate of pinnate type, convergent.

FLOWERS. White, numerous, crowded in terminal cymes, hermaphroditic, cyclic, zygomorphic; aestivation valvate; calyx hexamerous, gamosepalous, persistent; corolla hexamerous, gamosepalous, tubular, regular.

Jasminum grandiflorum

NOMENCLATURE. "Spanish jasmine" in English; "jati" in Sanskrit; "chambeli" in Gujrati.

HABIT. Large, glabrous, climbing shrub.

LEAVES. Opposite, imparipinnate, three to four inches long, exstipulate; leaflets three to seven, sessile, ovate, glabrous, acute, entire; petioles marginate, apical ones partially united with uppermost pair; venation bipinnate-reticulate, convergent.

FLOWERS. White, numerous, crowded, faint pinkish, streaks on outside, in terminal cymes, hermaphroditic, cyclic, zygomorphic; aestivation twisted; calyx linear, pentamerous, gamosepalous, persistent; corolla pentamerous, gamopetalous; stamens two, polyadelphous, epi-

petalous, inserted, adnate; gynoecium monocarpellary, superior, bilocular.

Two varieties of *J. grandiflorum* are found in Uttar Pradesh: *a*) with yellowish-green stems and pure white blossoms; *b*) with light-green stems, violet corners on outer side of petals.

Jasminum sambac

NOMENCLATURE. "Moghra" and "bela" in Hindi; "batmogri" in Gujrati and Marathi; "zambak" in Persian; "mallika phul" in Bengali; "malli gai" in Tamil; "Arabian Jasmine" in Oriental poetry.

HABIT. Erect shrub.

LEAVES. Pulvinous, petiolate, exstipulate, oval, opposite, acute, glabrous, entire; venation pinnate-reticulate, convergent.

FLOWERS. White, solitary, very fragrant, petiolate, zygomorphic; calyx one-half to one inch long, villous, persistent, with teeth one-third to one-half inch long; corolla regular, gamopetalous, rotate; petals numerous, in four or five whorls, ¾″ to ⅞″ long, glabrous; stamens epipetalous, inserted.

Cultivation and Harvesting

The soil and climatic conditions are almost the same for all types of jasmine. The plants can be easily cultivated in fields where proper irrigation facilities exist and where there is full exposure to the sun. They require frequent irrigation before and during the blooming period. Propagation is by cuttings from old plants, sown in well manured plots in December or January; or branches are buried underground for some time and then cut in the rainy season, to be transplanted in fields, four to five feet apart. Farmyard manure is used as fertilizer.

In general, a jasmine field lasts ten to 15 years, but on well drained soil a plantation may survive much longer. There

FIG. 1. *Jasminum auriculatum.*

FIG. 2. *Jasminum sambac.*

TABLE I

HARVESTING PERIODS, FLOWER YIELDS AND OTHER DATA

	J. grandiflorum	*J. sambac*	*J. auriculatum*
Period of harvesting	August to October	April to July	August to November
Yield of flowers per acre in India ...	300–350 kg.	600–1,000 kg.	15–20 kg.
Yield of flowers per acre elsewhere ..	1,200–1,600 kg. in France	.....	.....
Price per 82 lbs. in Indian rupees ...	Rs. 30–45/–	Rs. 25–35/–	Rs. 35–50/–
No. of flowers per kgm.	10,000–12,000	3,000–4,000	26,000

are 1,600 to 2,000 plants per acre, and the bushes must be trimmed every year to facilitate harvesting of the flowers.

The customary harvesting practice in India consists of plucking mature buds in the evening; the buds open two or three hours later. This procedure is usually followed despite its having been shown that the maximum amount of perfume from *J. grandiflorum* is obtained from open flowers picked between 6 and 10 A.M., and that the perfume from flowers gathered at daybreak is the finest. The maximum oil content in the blossoms of this species occurs in September.

Extraction

The valuable perfume components of jasmine flowers, like those of many others, are obtained by three processes—distillation, solvent extraction and one known as " enfleurage ", or by a modification of the third of these.

In India the three species *J. auriculatum*, *J. grandiflorum* and *J. sambac* are processed by one or more of these techniques, but in southern France (Grasse), Italy, Egypt and Morocco, *J. grandiflorum* is utilized almost exclusively and for the most part by the solvent procedure.

Solvent Extraction. Petroleum ether or benzene are the solvents used in this method, and the products obtained are known as " concretes ". The yield of concrete from jasmine varies from 0.28% to 0.31% of the weight of fresh flowers. Concretes, as such, are not employed directly in the manufacture of perfumes. The floral ingredients in them must first be extracted with alcohol into products known as " absolutes " or " absolute essences ". By such treatment absolutes varying from 40% to 52% on the weight of the concretes are obtained. *J. sambac* flowers in Grasse have yielded 0.2% concrete, which gave 50% absolute, and East African blossoms of the same species have furnished 0.29% absolute on the weight of flowers. Data concerning the yields of *J. auriculatum* are not available.

Distillation. This is the method for obtaining pure jasmine oil and is carried out, not directly on the blossoms but on the concretes obtained from them. Sicilian and Calabrian concretes, treated with super-heated steam at 88° to 92° C. and at 35 to 40 mm. pressure, have given 10.6% to 23.5% volatile oil. In India perfumers prepare attars by absorbing steam-distilled vapours of jasmine into sandalwood oil.

Enfleurage. In this process a thin layer of purified fat (lard) is applied on both sides of glass plates supported on wooden frames called " chassis ", which are placed one above the other so that flowers placed on the larded plates are enclosed between the two layers of fat which absorbs the perfume emitted by them. The exhausted flowers are removed periodically, depending on the type of blossoms used and the humidity. Renewal of the flowers is continued till the fat is fully saturated. The perfumed

fat, called "pomade", is removed from the chassis and treated with 95% alcohol to extract the absolute. This technique, developed in France during the XVIII century, takes care of only about 15% of all flowers harvested in the Grasse region, the remaining 85% being handled by solvent extraction, despite the fact that the yield of absolute by enfleurage is greater.

In India more than half of the *J. auriculatum* and *J. sambac* flowers are used for the manufacture of perfumed hair oils by the following modification of the enfleurage process. Either the white or black variety of til seeds (*Sesamum indicum*) are first soaked in water, to remove their covering, then dried in the sun, and next divided into lots of six maunds (maund = 82.29 lb.), each lot being termed a "ghan". The ghans, in turn, are divided into three classes—sira, baju and raddi according to the quality and quantity of the flowers used in them.

To prepare the best or sira grade, fresh flowers and the til seeds are spread in five or six alternate layers one over the other on the floor of a shed. After 10 to 12 hours, or less, depending on the atmospheric humidity (less humidity, the greater the time of contact) the flowers are separated from the seeds by sifting. The same seeds are then spread in alternate layers with a second batch of fresh flowers. This procedure is repeated until 12 to 18 maunds of flowers have been used with each six-maund ghan of seeds. The quantity of flowers mixed with the same ghan is increased from day to day, beginning at 10 srs. and ending with 17½ srs. per ghan per day. The total quantity of flowers used with a ghan varies from place to place according to local practice, and also depends on the price of both flowers and seeds. The aim of the manufacturer is to use the minimum quantity of blossoms in obtaining the best quality of perfume. Humid atmosphere is unfavorable for drying moist seeds as improperly dried seeds cause rancidity in the oil and spoil the odour.

The properties of the oils prepared from the above three varieties of jasmine flowers are given in Table II.

TABLE II

PROPERTIES OF OILS OBTAINED FROM THE THREE PRINCIPAL SPECIES OF *Jasminum* CULTIVATED IN INDIA

	J. sambac					*J. grandiflorum*	*J. auriculatum*
	Kanauj	Aligarh	Sikandarpur (Ballia)	Ghazipur	Kanpur		Ghazipur
% yield of otto	0.02–0.02%	0.023%	0.023%	0.02–0.022%	0.02–0.03%	0.02–0.025%	0.02%
Sp. gr. at 30° C.	0.9727	0.9728	0.9795	0.9797	0.9769	0.9814	0.9548
Ref. index at 30° C.	1.506	1.507	1.507	1.507	1.506	1.497	1.5185
Opt. rotation	2°12′	...	...	...	...	...	...
Acid value	6.4	7.6	4.7	1.5	11.36	1.2	7.2
Ester value	121.2	126.6	131.52	125.19	129.64	276.8	132.84
S.V. after acetylation	239.2	229.8	241.3	235.9	233.7	...	275.3
Esters as benzyl acetate	32.45%	33.89%	35.2%	33.52%	34.7%	74.8%	35.7%
Total alcohol as linalol	35.58%	30.73%	32.90%	33.16%	30.99%	...	43.8%
Methyl anthranilate	2.88%	...	2.97%	3.51%	3.06%	0.45%	6.1%
Indole	2.75%	...	...	2.82%	...	1.75%	2.82%
Benzyl alcohol	...	...	...	...	...	15.46%	...
Jasmone	...	...	...	...	...	3.0%	...

Utilization Abstract

Sassafras. As with many other folk remedies, sassafras today does not have large significance in our commerce. In the past, however, sassafras played an important role in the trade of the early American colonists. Fantastic stories of the capacity of various parts of the tree to cure most of the common ailments of man reached Europe, and the resulting demand made this plant one of the first exports of the Virginia Colony at Jamestown.

Today the plants are considered almost as weeds in fence rows or as an occasional volunteer in cut-over forests. They are seldom found much larger than a foot in diameter of trunk, but in some regions of the eastern United States, they achieve a much greater diameter and respectable heights. *Sassafras variifolium*, a member of the Laurel family, has a very rough bark, with young twigs a pleasant smooth green. The leaves vary in shape from simple elliptic to bi- and trilobed, giving the name to the species.

The trees have been used in several products, as lumber, and for extracts of bark and wood. The wood of sassafras weighs 31 pounds per cubic foot, has little tendency to check or warp, produces an attractive figure and grain, is quite durable in contact with soil and water. The lumber has limited use in articles of furniture manufacture. Various extracts are made from bark and wood of root and stem. An orange or yellow dye, said not to fade in the sun, has been derived from the bark and used for dyeing cloth. The essential oils of sassafras may be used as a flavor for soft drinks or in perfume for soap.

Sassafras tea is familiar to residents of the eastern United States, most frequently in rural areas. Breewd from the inner bark of the root, the tea is drunk as a spring tonic. The tea may have some therapeutic effect, but modern medical botanists describe it as an " aromatic stimulant ".

Whether any real value lies in the extracts remains to be determined. Many such plants known for years in folk medicine and passed off as mere superstition have come back to play an important role in modern day life. (Anon., *News from Home 18* (*2*): *10–14. 1957*).

BOOK REVIEW

Rauwolfia: Botany, Pharmacognosy, Chemistry, and Pharmacology. Robert E. Woodson, Heber W. Youngken, Emil Schlittler, and Jurg A. Schneider. x + 149 pages. Little, Brown and Co. 1957. $5.50.

"The unraveling of the mysteries of *Rauwolfia* was not the work of a single scientific discipline. This is exemplified by the experts who have assembled the data in this text".—Foreword by Arnold J. Lehman. Aside from the value of the text for workers in modern medicine, one of its greatest values is this inter-disciplinary study. In many other areas of science, cooperative work has paid handsome dividends, but the incorporation of the studies of a taxonomic botanist in such a work has certainly been an infrequent occurrence. One must thank, I suppose, the directors of Ciba Pharmaceutical Products, Inc for their forethought in this matter.

The value of the book to students of tranquilizing drugs is that it assembles the pertinent knowledge of one related group of drugs into a usable format. There are four sections, one for each of the subtitles, in the order listed. In each of the sections, an effort is made to examine the significant contributions from that discipline. Certainly any taxonomist would recognize that the format for Woodson's part diverges considerably from that which a separate systematic study of the genus *Rauwolfia* would require. This is true of all the sections.

Some discontinuity results from the divisions employed, and frequently there is an overlapping of information contained in the introductory portions of each chapter. In the botanical treatment of *Rauwolfia*, Woodson places *R. canescens* and *R. heterophylla* in synonymy under the American species *Rauwolfia tetraphylla*. In the chapter on pharmacognosy, Youngken discusses *Rauwolfia canescens* and *Rauwolfia heterophylla* under separate headings. There are some slight differences in anatomical detail and alkaloid content listed for these two names, and this may be a valid differentiation, but it seems that there is still a gap between these two areas, taxonomy and pharmacognosy.

The order of presentation of the material seems valid, with the basic data on the plants themselves introducing the study. In this beginning is included the information of the status of the taxonomy for the family Apocynaceae, a definition of the genus *Rauwolfia*, a listing of the known species, and their distribution. Cultivation of the species of drug value is discussed. One of the main problems with these plants which have suddenly become of economic value is the lack of knowledge of proper cultivation practices. Which soil type, which climatic situation, which time of year for planting, which genetic variants, and other problems still need study.

A systematic study of the anatomy of the roots of species normally used commercially, and several other species is presented. Sections were made from dried roots, and the data should be valid for identification of commercial roots. A key to several species based on root anatomy is presented.

The pharmacognosy of *Rauwolfia* follows the botanical descriptions, presenting data on nine species which produce significant drugs.

The important alkaloid bases of therapeutic significance which have been reported on are reserpine (the first isolated), rescinnamine, and deserpidine. The alkaloids extracted from different *Rauwolfia* species are listed. These are placed in three categories:

Yellow-colored, strong anhydronium bases,
Indoline alkaloids of intermediate basicity,
Weakly basic indole alkaloids.

Ultraviolet spectra and pKa values are indicative of the groups to which the different alkaloids belong.

The general chemical aspects of these alkaloids forms Part I of Chapter 3, a thorough discussion of the structure and stereo-chemistry forms Part II, and the last, Part III, is

devoted to the synthetic studies related to the *Rauwolfia alkaloids*.

The largest amount of information available in Chapter 4 is concerned with the biological activities of reserpine. Data concerning other alkaloids are presented in short summary, with the most obvious conclusion that there is no real knowledge of the biological effects of most of them. Classification of reserpine is difficult since it may not be categorized with any classic groups. Here it is described as "phrenotropic—a drug which influences the function of the mind and affective behavior". The primary mode of action of reserpine is an attack localized in the central nervous system, with peripheral gastrointestinal effects. The reasons for the long term action of the drug is not clear, but it is hypothesized that either a metabolic alteration of the reserpine molecule produces an active molecule or that reserpine causes the release of serotonin with resultant long-term action after the actual removal of the drug.

The major therapeutic value of *Rauwolfia* alkaloids, of which reserpine and some close analogs are the most important, lies in the treatment of schizophrenia, maniacal states, Sydenham's chorea, and withdrawal symptoms in chronic alcoholism and drug addiction. It is likewise used for treatment of hypertension and as a tranquilizing agent in states of tension and anxiety.

Altogether, this is a well conceived reference work. The complimentary distribution to many institutions and individuals by CIBA Pharmaceutical Products, Inc. is meritorious.